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Essays on Fiscal and Monetary Policy in Open Economies

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Essays on Fiscal and Monetary Policy in Open Economies

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Dedicated to my family.

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Essays on Fiscal and Monetary Policy in Open Economies

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In the first chapter, I quantify the welfare effect of eliminating the U.S. capital income tax under international financial integration. I employ a two-country, heterogeneous-agent incomplete markets model calibrated to represent the U.S. and the rest of the world. Short-run and long-run factor price dynamics are key: after the tax reform, post-tax interest rate increases less under financial openness relative to autarky. Therefore the wealth-rich households gain less. Post-tax wages also fall less, so the wealth-poor are hurt less. Hence, the fraction in favor of the reform increases, although the majority still prefers the status quo. Aggregate welfare effect to the U.S. is a permanent 0.2 % consumption equivalent loss under financial openness which is 85.5 % smaller than the welfare loss under autarky.

The second chapter aims to answer two questions: What helps forecast U.S. inflation? What causes the observed changes in the predictive ability of

variables commonly used in forecasting US inflation? In macroeconomic analysis and inflation forecasting, the traditional Phillips curve has been widely used to exploit the empirical relationship between inflation and domestic economic activity. Atkeson and Ohanian (2001), among others, cast doubt on the performance of Phillips curve-based forecasts of U.S. inflation relative to naive forecasts. This indicates a difficulty for policy-making and private sectorâs long term nominal commitments which depend on inflation expectations. The literature suggests globalization may be one reason for this phenomenon. To test this, we evaluate the forecasting ability of global slack measures under an open economy Phillips curve. The results are very sensitive to measures of inflation, forecast horizons and estimation samples. We find however, terms of trade gap, measured as HP-filtered terms of trade, is a good and robust variable to forecast U.S. inflation. Moreover, our forecasts based on the simulated data from a workhorse new open economy macro (NOEM) model indicate that better monetary policy and good luck (i.e. a remarkably benign sample of economic shocks) can account for the empirical observations on forecasting accuracy, while globalization plays a secondary role.

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Chapter 1

The Redistributional Consequences of Tax Reform Under Financial Integration

1.1 Introduction

Should the U.S. capital income tax be eliminated? Capital tax cuts in general, such as the one introduced by the Bush administration in 2003 and expected to expire by the end of 2012, have been the subject of intense debate in both academic and policy circles.[1] Supporters of these tax reforms argue that they promote investment and output, and improve efficiency. Opponents, on the other hand, are concerned with the negative wealth distributional consequences of these reforms. They suggest that a capital tax cut primarily helps the rich. I contribute to this discussion by incorporating into the analysis the fact that the U.S. economy has become increasingly integrated with the world financial markets over the past 30 years. Taking as given a realistic wealth distribution for the U.S. in a heterogeneous agent-incomplete markets framework, I explore how both macroeconomic aggregates and the distribution of wealth across households respond to replacing the capital income tax with

[1] The Bush tax reform, known as the Jobs and Growth Tax Relief Reconciliation Act (JGTRRA), encompasses a cut in both capital gains and dividend taxes. This paper however, focuses only on capital gains taxes and aims to address a central question in this literature regarding the elimination of capital income taxes.

higher labor income taxes.

Prior work studying the distributional effects of tax reforms has focused only on closed economy models, which assume that the U.S. households have no access to international financial markets. This assumption is clearly in conflict with reality.[2] In fact, the U.S. should be considered as a large open economy. Therefore, a tax reform of this size can affect the dynamics of world factor prices and induce large capital inflows from abroad. These dynamics in turn alter the quantitative impact on the wealth redistribution and determine which households may favor the tax reform. This study is the first attempt in the literature to quantify the desirability of capital income tax reforms in which the U.S. is modelled as part of a financially integrated global economy.

Following Chamley (1986) and Judd (1985), a main finding in the Ramsey literature is that in the standard neoclassical growth model it is not optimal to tax capital in the long run. In a similar framework, a related policy prescription by Lucas (1990) was that if the highly distortionary capital income tax were to be replaced by a higher (and less distortionary) labor income tax in the U.S., households could enjoy significant welfare gains (a 1 percent increase in annual consumption) as the capital income tax cut stimulates investment, output and consumption.[3] While the elimination of the capital income tax seems

[2] The U.S. net foreign asset position reached -17% of its GDP in 2007, while the current account deficit reached 5.1%. Source: Lane and Milesi-Ferretti (2007) and World Development Indicators.

[3] As Lucas put it, the welfare gain is twice that of eliminating 10% inflation, and about 20 times that of eliminating the business cycle.

attractive in these closed economy models, it becomes even more attractive in a financially open economy since capital inflows from abroad amplify the stimulus to investment and output and enable greater consumption smoothing during the transition period. Mendoza and Tesar (1998) pointed out the importance of the international borrowing channel, in a two-country representative agent model. In such a setting, the elimination of the capital income tax led to welfare gains to the U.S. up to 33% more than in a closed economy model.

My model economy preserves these economy-wide long run potential gains from eliminating the capital income tax. However, the government's need to increase other taxes, such as the labor income tax, in order to maintain fiscal solvency has adverse wealth distributional effects. In particular, the tax reform may be opposed by households who hold low levels of assets and rely predominantly on labor income; while supported by wealthy households who receive proportionally more capital income. Indeed, Domeij and Heathcote (2004) quantitatively showed that in a closed economy, given the highly concentrated U.S. wealth distribution, the elimination of the capital income tax would not be supported by the majority of the population. I argue that in order to make a more realistic assessment of the desirability of a tax reform, the U.S. should be modelled as an open economy.

The importance of looking at the problem under financial openness can be understood through the following mechanism. A capital income tax cut increases the demand for capital by the production sector, raising both the equilibrium capital stock and the after-tax interest rate in the economy. While this also implies a rise in wages, after-tax wages decline since the capital income tax cut is accompanied by a sufficiently higher labor income tax. The qualitative properties of this mechanism are common to both closed economy and large open economy models, but the quantitative effects differ. In a two-country setting, the policy-induced increase in the return to capital leads to an inflow of capital from the rest of the world. As a result, interest rates increase by less than under autarky. Hence, the gains to rich households are smaller.[4] In addition, the more rapid accumulation of capital raises the marginal product of labor relative to autarky, thereby mitigating the decline in after-tax wages. This implies that poor households are not hurt by the reform as much as a closed economy model would predict. This motivates the question of the current paper: are these quantitative changes in wage and interest rate dynamics under financial openness sharp enough that a majority will support the tax reform?

To answer this question, I employ a two-country version of the Aiyagari (1994) model where the two countries are calibrated to represent the U.S. and the rest of the world (ROW).[5] The framework is related to the heterogeneous-agent incomplete markets models first analyzed by Bewley (1986), İmrohoroğlu (1989), Huggett (1993), as well as Aiyagari (1994) which is a one-sector neo-

[4]Throughout the text, 'rich' and 'poor' are used interchangeably for 'wealth-rich' and 'wealth-poor', respectively, unless stated otherwise.

[5]ROW represents Euro Area, Japan, oil exporters and emerging Asia. A list of the countries are given in the appendix.

classical growth model with uninsurable idiosyncratic labor income risk and borrowing constraints.[6] I further enhance the model by including government policy. In this setting, I conduct an experiment *à la* Lucas (1990) by introducing a unilateral, unanticipated and permanent capital income tax cut in the U.S.[7] To finance a fixed stream of government expenditures, both countries adjust their labor income taxes such that the present value of the government budget holds. The U.S. economy is simulated both under financial autarky and financial integration, and the consequences of the reform are evaluated taking into account both steady state gains and the transitional dynamics. In particular, households with various initial wealth and labor productivity levels are tracked over time after the reform takes place, and their welfare is compared to the *status quo*. The calibration of the benchmark model of financial openness is realistic in the sense that at the initial steady state equilibrium both macroeconomic aggregates and asset holdings across different wealth groups in the U.S. match the data closely.

I show that financial openness plays a key role in mitigating the adverse redistributional effects of the tax reform. For instance, households that are at the top 1% of the U.S. wealth distribution prior to the reform enjoy around a permanent 12% consumption equivalent gain under financial autarky, while this number is reduced to 6% under financial integration. On the other hand,

[6] This class of models has become the standard workhorse approach in investigating the relationship between macroeconomic phenomena and their distributional consequences.

[7] See Aiyagari and McGrattan (1998), Flodén (2001), Domeij and Heathcote (1994) and Röhrs and Winter (2011) for examples of fiscal policy reforms in a heterogeneous agent-incomplete markets framework.

households at the bottom 1% of the wealth distribution are estimated to suffer a permanent 5% consumption equivalent loss under financial autarky, while the loss shrinks to 1.8% under financial integration. Moreover, the fraction of the population with positive welfare gains is estimated as 3% larger under financial openness than under financial autarky, with about 29% of the U.S. households in favor of the reform.[8] Hence there is not a majority to support a capital income tax cut when financial openness is taken into account.

A second result is that the aggregate welfare gain to the economy due to the elimination of capital tax is negative, although this welfare loss is not too large: a permanent 0.24% loss in consumption. The closed economy predicts a permanent 1.55% decline in consumption, implying a cost that is 6.5 times the cost in an open economy. In both model economies, a tax cut yields steady state gains but, perhaps surprisingly, the steady state gain under financial openness is lower. This is because in the long run, households service the foreign debt accumulated during the transition, thereby sacrificing some of their consumption in the new steady state. Nevertheless, the transition to the new steady state is less costly for the open economy since international borrowing makes the transition path of aggregate consumption smoother.

The aggregate welfare result is in line with the literature studying capital taxation under incomplete asset markets characterized by uninsured idiosyncratic risk and borrowing constraints. Domeij and Heathcote (2004) find

[8] According to U.S. Census Bureau data (July 2012), this difference corresponds to roughly 9.9 million people on average.

a negative result. Ábrahám and Cárceles-Poveda (2009) report similar results studying tax reforms with endogenous borrowing constraints and flat rate taxes.

For a closed economy and in the presence of precautionary savings motive, Aiyagari (1995) suggests that households accumulate too much capital so that taxing capital helps bring the capital stock to the optimum level. Therefore, a positive capital income tax is optimal in the long run. İmrohoroğlu (1998) and Conesa, Kitao and Krueger (2009) study tax reforms in life cycle models when households are uninsured against idiosyncratic labor income risk and face borrowing constraints. In these environments, replacing the capital income tax by a higher labor income tax imposes greater burden on agents when they are younger and liquidity constrained, reducing their ability to smooth consumption. They also quantitatively characterize the optimal capital tax rate and find that a positive tax is optimal. It is still an open question what the optimal capital income tax should be when we move away from financial autarky. However, characterizing the optimal capital income tax is beyond the scope of this paper and left as future work.

In open economy models, domestic tax policy has been shown to have effects on other countries' tax policies. Klein, Quadrini and Ríos-Rull (2005) and Quadrini (2005) analyze tax policy when governments conduct optimal fiscal policy without commitment under international mobility of capital. Mendoza and Tesar (2004) evaluate the European tax competition in a two-country neoclassical growth model. In the current paper, the ROW labor income tax needs to be altered in response to an elimination of the U.S. capital income tax. Since the elimination of the U.S. capital income tax does not create gains for the majority of the population, the reform is not desirable to implement. Hence, for this particular reform, we do not mention any need for the ROW government to give a strategic response by altering the ROW capital income tax.

This study is also related to two papers by Mendoza, Quadrini and Ríos-Rull (2007; 2009). In a two-country heterogeneous-agent model, they depict how global financial imbalances have emerged as well as quantifying the welfare effects of financial integration (Mendoza, Quadrini and Ríos-Rull (2007)). The current framework is complementary to this strand of the literature in two dimensions. First, it explains how a capital tax cut may deteriorate the U.S. net foreign asset and current account imbalances. In this case, increasing the capital taxes, rather than decreasing, may help prevent the global financial imbalances from reaching unsustainably high levels. Second, the current paper helps us understand how tax policy may mitigate or exacerbate the negative redistributional consequences of financial globalization through wage and interest rate dynamics.

I proceed with the model in the next section. In section 3, I discuss the long run equilibrium effects of a capital income tax cut and explain the numerical solution as well as the calibration strategy. Section 4 provides the results and section 5 concludes.

1.2 The Model

I introduce a two-country heterogeneous-agent, incomplete markets model. There are two financially integrated countries in the world economy, *Home* and *Foreign*. Foreign variables are denoted by an *asterisk* (*). For convenience, the model is presented for *Home* only and *Foreign* variables are introduced when needed.

1.2.1 Production sector

In each country, aggregate output Y_t is produced by a representative firm using aggregate capital K_t, and aggregate labor N, according to a constant returns to scale production function:[9]

$$Y_t = F(K_t, N) \tag{1.1}$$

Capital depreciates at the rate $\delta \in (0, 1)$. All parameters of production are the same across countries. In each country, households competitively supply physical capital to the firms at a real rental rate r_t^k and labor (inelastically) at a real wage rate w_t where both factors are assumed to be immobile internationally. Perfect competition in factor markets implies firms make zero profits in equilibrium.

[9]Following the literature, all aggregate variables are denoted by capital letters.

1.2.2 Government

The government in each country collects tax revenues from labor and equity and issues debt D_{t+1} at each period t to finance an exogenous stream of real per capita government expenditures, G. The real one period return to government debt is risk-free and equal to r_t^d. In contrast to private debt, public debt is assumed not to be traded internationally as there would not be a well-defined portfolio choice between the two assets. The government does not make any transfers. At $t = 0$, the government introduces a tax reform so that a new pair of taxes τ^n and τ^k are imposed. The date$-t$ budget constraint for each government is as follows:

$$G + r_t^d D_t = D_{t+1} - D_t + N w_t \tau^n + K_t (r_t^k - \delta)\tau^k \tag{1.2}$$

$$G^* + r_t^{d*} D_t^* = D_{t+1}^* - D_t^* + N^* w_t^* \tau^{n*} + K_t^* (r_t^{k*} - \delta)\tau^{k*} \tag{1.3}$$

given D_0 and D_0^*

1.2.3 Households

Each country is inhabited by a continuum of unit mass of households which receive shocks to labor efficiency, $\varepsilon_t \in E$ which are i.i.d. across households and persistent over time. This is the only uncertainty in the model.

Household choices in period t are made after observing ε_t. A household receiving a shock ε_t earns a labor income $\varepsilon_t n w_t$. The efficiency shock ε_t evolves over time according to a m-state ($m < \infty$) first-order Markov process defined with an $m \times m$ transition probability matrix $\Pi = [\pi_{ij}]$, where $\pi_{ij} = \Pr(\varepsilon_{t+1} = \varepsilon_j | \varepsilon_t = \varepsilon_i)$. All elements of Π are non-negative and each row sums up to 1. I denote the finite history of these shocks from date 0 up to date t by $\varepsilon^t = \{\varepsilon_0, ..., \varepsilon_t\}$. To denote the probability distribution over E at any period t, I use the vector $p_t \in \mathbb{R}^m$. Initial distribution is denoted by p_0 and the date$-t$ distribution is then given by $p_t = p_0 \Pi^t$. E has a unique ergodic set, no cyclically moving subsets and for any given p_0, $\{p_t\}_{t=0}^{\infty}$ converges to the (unique) limit p^*. I start by assuming $p_0 = p^*$, therefore the aggregate effective labor supply N converges to a constant.

Households maximize their expected life-time utility given by

$$E_0 \left[\sum_{t=0}^{\infty} \beta^t U(c_t) \right] \tag{1.4}$$

where $\beta \in (0, 1)$ is the discount rate. The period utility function $U(\cdot)$ is strictly increasing, strictly concave and continuously differentiable. In each period, a household's consumption is denoted by c_t and hours worked by n. I assume a single composite consumption good, traded across countries.

Households face the following budget constraint taking as given the relative prices and tax rates at each period

$$c_t + \underbrace{b_{t+1} + d_{t+1} + k_{t+1}}_{\equiv a_{t+1}} \leq \varepsilon_t n w_t (1-\tau^n) + \underbrace{[(r_t^k - \delta)(1-\tau^k)+1]k_t + (1+r_t^d)d_t + (1+r_t)b_t}_{\equiv (1+r_t)a_t}$$

Household expenditures are given on the left-hand side of the budget constraint. Accordingly, they may purchase consumption goods c_t and borrow or lend in the amount of their asset holdings, a_{t+1}. Specifically, households may invest in either 1-period, non-state-contingent private bonds, b_{t+1} which are internationally traded at an interest rate r_t, non-state-contingent public bonds d_{t+1}, which are traded only domestically at an interest rate r_t^d or capital goods, k_{t+1}. The right-hand side of the budget constraint includes factor and non-factor income of the household. Households' after-tax labor income is given by $\varepsilon_t n w_t (1-\tau^n)$ where $\tau^n \in [0,1]$ is a constant, flat-rate labor income tax. A flat-rate, constant tax rate $\tau^k \in [0,1]$ is also imposed on households' net return from physical capital and therefore physical capital has an after-tax return of $1 + (r_t^k - \delta)(1-\tau^k)$. Both tax rates may differ across countries. Finally, private bond holdings yield an income equal to $(1+r_t)b_t$ and public debt holdings yield $(1+r_t^d)d_t$. Notice that optimal portfolio allocation implies

$$r_t = r_t^d = (r_t^k - \delta)(1-\tau^k) \tag{1.5}$$

Hence, the international return on private bonds is equal to the net-of-tax return on physical capital at each period. Since the model assumes no aggregate TFP shocks and the real one-period return from private and public debt are guaranteed (assuming that there is no default on private or public debt in any countries) all three assets are considered perfect substitutes. Therefore, we are able to state the household's problem without considering the portfolio composition of assets. The budget constraint can now be re-written as

$$c_t + a_{t+1} \leq \varepsilon_t n w_t (1 - \tau^n) + (1 + r_t) a_t \tag{1.6}$$

In each period, individuals are able to borrow up to an exogenous limit, denoted by $\underline{a}$. Therefore at any period t :

$$a_t \geq \underline{a}. \tag{1.7}$$

The borrowing constraint is the same for all individuals in a country and the same across countries. When households face a borrowing constraint, this implies that a household can have a long position in one type of asset while having a short position in another to the extent that the net asset position does not fall below the limit.

Define $s_t = (a_t, \varepsilon_t)$ as the state vector of the household at any t. Given the deterministic sequences of factor prices $\{w_t, r_t^k, r_t^d, r_t\}_{\tau=0}^{\infty}$, a constant level of taxes and government expenditures $\{\tau^n, \tau^k, G\}$ and initial conditions $s_0 = (a_0, \varepsilon_0)$ in any country, a household maximizes (4), subject to (6) and (7).

The resource constraint in *Home* is given by (and similarly defined for *Foreign*)

$$C_t + I_t + G + B_{t+1} - B_t = Y_t + r_t B_t \tag{1.8}$$

where $I_t \equiv K_{t+1} - (1-\delta)K_t$ is net domestic, private investment and $B_t \equiv A_t - K_t - D_t$ is the date$-t$ net foreign asset position for *Home* and B_0, K_0 and D_0 given. We similarly define the net foreign asset position for *Foreign*, $B_t^* \equiv A_t^* - K_t^* - D_t^*$ and take B_0^*, K_0^* and D_0^* as given. Having defined the net foreign asset position, we can also define the *Home* current account, $CA_t \equiv B_{t+1} - B_t$, net exports, $NX_t \equiv B_{t+1} - B_t(1+r_t)$ and net factor payments, $NFP_t \equiv r_t B_t$ which can be similarly defined for *Foreign*.

1.2.4 Equilibrium

Let A be the set of the possible values of household wealth (set of endogenous states). Since households are allowed to borrow up to an exogenous (negative) limit, $\underline{a}$, $A = [\underline{a}, \infty]$. Let $(A, \mathcal{A})$ and $(E, \mathcal{E})$ be measurable spaces where $\mathcal{A}$ denotes the Borel set that are subsets of A and $\mathcal{E}$ is the set of all subsets of E. Let $(S, \mathcal{S}) = (A \times E, \mathcal{A} \times \mathcal{E})$ be the product space and S is the set of all possible household states. The solution to the household's problem provides the decision rules for consumption, $c_t = h_c(a_t, \varepsilon_t)$ and asset holdings, $a_{t+1} = h_a(a_t, \varepsilon_t)$ given the initial conditions (a_0, ε_0) and if the history of idiosyncratic shocks up to t is ε^t . These rules determine the evolution of the distribution of agents over s_t. I define the joint distribution of households across both household wealth and labor efficiency at date t by $\Gamma_t(a_t, \varepsilon_t)$. A household with the state s_t will have a state vector lying in S_{t+1} next period, given this period's distribution $\Gamma_t(a_t, \varepsilon_t)$ and the decision rules $h_c(a_t, \varepsilon_t)$ and $h_a(a_t, \varepsilon_t)$. Given $\Gamma_0(a_0, \varepsilon_0)$, the distribution evolves with the law of motion defined by

$$\Gamma_{t+1}(a_{t+1}, \varepsilon_{t+1}) = \sum_{\varepsilon} \Pi(\varepsilon_{t+1}|\varepsilon_t)\Gamma_t(h_a^{-1}(a_{t+1}, \varepsilon_t), \varepsilon_t) \tag{1.9}$$

The definition of competitive equilibrium under financial integration is given below.

Definition 1 ***(Financial integration)*** *Initial joint distributions of individuals across both individual wealth and labor efficiency shocks in the two economies are given by $\Gamma_0(a_0, \varepsilon_0)$ and $\Gamma_0^*(a_0^*, \varepsilon_0^*)$. Idiosyncratic risk washes out in aggregate. Given initial distributions, net foreign asset positions, B_0, B_0^* , public debt D_0, D_0^* , capital stock K_0, K_0^* , fiscal policy instruments $\{G, G^*, \tau^n, \tau^{n*}, \tau^k, \tau^{k*}\}$, a general equilibrium under financial integration is defined by*

1. Households' policy functions $\{h_c(s_t),\ h_c^*(s_t),\ h_a(s_t),\ h_a^*(s_t)\}_{t=0}^{\infty}$
2. A competitively determined, deterministic path of relative prices $\{w_t, w_t^*, r_t^d, r_t^{d*},$

   $r_t^k, r_t^{k*}, r_t\}_{t=0}^{\infty}$
3. A deterministic path of macroeconomic aggregates $\{C_t, C_t^*, A_{t+1}, A_{t+1}^* K_{t+1}, K_{t+1}^*,$

   $B_{t+1}, B_{t+1}^*, D_{t+1}, D_{t+1}^*\}_{t=0}^{\infty}$
4. Distributions $\{\Gamma_t(a_t, \varepsilon_t), \Gamma_t^*(a_t^*, \varepsilon_t)\}_{t=1}^{\infty}$

such that:

- Given the sequences of plans and policies, the plans are optimal for individuals and firms (as described below).

- The aggregates are consistent with household behavior:

$$\int_s c_t(s_t)d\Gamma_t = C_t, \int_s a_t(s_{t-1})d\Gamma_t = A_t, \text{ for all } t. \tag{1.10}$$

$$\int_s c_t^*(s_t)d\Gamma_t^* = C_t^*, \int_s a_t^*(s_{t-1})d\Gamma_t^* = A_t^*, \text{ for all } t. \tag{1.11}$$

- Labor markets clear domestically:

$$\int_s \varepsilon_t n d\Gamma_t = N \text{ and} \int_s \varepsilon_t n^* d\Gamma_t^* = N^*, \tag{1.12}$$

- Goods market clears:

$$C_t + C_t^* + I_t + I_t^* + G + G^* = F(K_t, N) + F(K_t^*, N^*), \text{ for all } t. \tag{1.13}$$

- Asset market clears:

$$B_t + B_t^* = 0, \text{ for all } t. \tag{1.14}$$

- The government budget holds in each country for all t.

- The sequence of distributions Γ_t, Γ_t^* is consistent with the initial distribution, individual policies and idiosyncratic shocks for $t \geq 1$.

1.2.5 Characterizing the equilibrium

The first order conditions from the optimization problems above are given below.

1. Firm's optimization:

$$r_t^k = F_K(K_t, N) \tag{1.15}$$

$$w_t = F_N(K_t, N) \tag{1.16}$$

The conditions for *Foreign* can be defined similarly. Hence factor prices in a given country depend on the aggregate capital and labor in that country.

2. Household's optimization:

$$U_c(s_t) = \beta E_{\varepsilon_{t+1}|\varepsilon_t}(1 + r_{t+1})[U_c(s_{t+1}) + \tilde{\lambda}(s_{t+1})] \tag{1.17}$$

where and $\tilde{\lambda}$ is the Lagrange multiplier associated with the borrowing constraint. Again, similar conditions are defined for *Foreign.*

1.3 The tax reform

The tax reform occurs at $t = 0$, when the world economy is in the steady state. The *Home* government introduces a permanent, unanticipated capital income tax cut, and increases the labor income tax to compensate the lost revenue. The reform is transmitted to *Foreign*, requiring a change in the labor tax to maintain fiscal solvency. Hence, Foreign introduces the tax reform at $t = 0$.

In this section, I provide some intuition for how tax reforms affect the steady-state allocations and how these results compare to those of a closed economy. I start with explaining how the international interest rate is determined in the steady state.[10] Assume that the production function is defined as Cobb-Douglas, $K^{\alpha}N^{1-\alpha}$ where α is the share of capital in production and also assume a general case in which labor supply is elastic.

Optimal portfolio choice in addition to firm's optimization implies that in the US after-tax net return to capital is equal to the interest rate:

$$(r^k - \delta)(1 - \tau_k) = (\alpha K^{\alpha-1} N^{1-\alpha} - \delta)(1 - \tau_k) = r \tag{1.18}$$

and similarly in *Foreign*:

$$(r^{k*} - \delta)(1 - \tau_k^*) = (\alpha K^{*\alpha-1} N^{*1-\alpha} - \delta)(1 - \tau_k^*) = r \tag{1.19}$$

If there exists an equilibrium with financial integration, these two conditions must yield:

$$r = (\alpha K^{\alpha-1} N^{1-\alpha} - \delta)(1 - \tau_k) = (\alpha K^{*\alpha-1} N^{*1-\alpha} - \delta)(1 - \tau_k^*) \tag{1.20}$$

[10] A closed economy version of a similar analysis can be found in Aiyagari (1995).

Therefore, after-tax net returns to physical capital are equalized across countries under financial integration. If an equilibrium with $\tau_k \neq \tau_k^*$ exists, this implies cross-country differences in aggregate equity and employment. In particular, if $\tau_k < \tau_k^*$, aggregate capital-aggregate labor ratio in Home is greater than Foreign, i.e. $K/N > K^*/N^*$. Notice that if physical capital were traded internationally and households paid taxes according to the resident principle then optimality would require that cross-country capital income tax rates be equalized, $\tau_k = \tau_k^*$.[11]

Moreover, government's steady-state budget constraint can be expressed as follows:

$$K + D = \frac{K}{1-\tau_k} + \frac{\tau_n w N - G}{r} \tag{1.21}$$

and

$$K^* + D^* = \frac{K^*}{1-\tau_k^*} + \frac{\tau_n^* w^* N^* - G^*}{r} \tag{1.22}$$

For a given set of tax rates and government expenditures, the $K + D$

[11] The resident principle requires that Home's households are imposed with the same tax rate for their domestic and foreign capital holdings. If equity were traded internationally and under the resident principle, the optimal portfolio allocation for Home residents would imply $r = (\alpha K^{\alpha-1}N^{1-\alpha} - \delta)(1-\tau_k) = (\alpha K^{*\alpha-1}N^{*1-\alpha} - \delta)(1-\tau_k)$ where $K = K_1 + K_2$ is the total domestic equity, K_1 is the (aggregate) domestic equity holding of Home residents and K_2 is the (aggregate) domestic equity holding of Foreign residents. A similar condition for Foreign residents can be stated as $r = (\alpha K^{\alpha-1}N^{1-\alpha} - \delta)(1-\tau_k^*) = (\alpha K^{*\alpha-1}N^{*1-\alpha} - \delta)(1-\tau_k^*)$ where total foreign equity can be defined similarly, $K^* = K_1^* + K_2^*$. In this case, cross-country capital tax rates would be equalized. Note also that even if countries differed in terms of TFP parameters this result would not change.

curve is decreasing in r for both countries. This is because as r rises, r^k rises and w falls. This implies lower K/N and lower N. Hence, K is also lower. This is similar for $Foreign$. As $r \to \infty$, K, N and $w \to 0$. On the other hand, if $r \to 0$, then K, N and $w \to \infty$. Supply of assets are determined by the household's problem and as defined above, aggregate household savings in each country are given by $\int_s a d\Gamma = A$ and $\int_s a^* d\Gamma^* = A^*$. As shown by Aiyagari (1994; 1995), A is an increasing function of r (which follows from the fact that household policy functions are increasing in r for each country. The equations (20)-(22) along with households' aggregate savings determine the equilibrium in the world asset market. Furthermore, under market incompleteness, aggregate asset holdings tend to infinity as r approaches the rate of time preference, $1/\beta - 1$ from below. As discussed by Aiyagari (1994;1995), a household wants to maintain a smooth marginal utility of consumption when $r = 1/\beta - 1$. When households face uninsurable labor income risk, however, the possibility of having bad income shocks in the future requires households to accumulate infinite amount of assets in order to maintain a smooth marginal utility of consumption profile.

An equilibrium with financial integration exists if there exists a steady state interest rate r such that

$$A(r) - K - D + A^*(r) - K^* - D^* = 0 \tag{1.23}$$

i.e. if the global asset market clears.

When countries are symmetric, i.e. if they have identical sets of tax rates and government spending, there exists an equilibrium with balanced trade (or zero net foreign asset position), i.e.

$$B(r) = A(r) - K - D = 0 \tag{1.24}$$

and

$$B^*(r) = A^*(r) - K^* - D^* = 0 \tag{1.25}$$

which yields asset market clearing at the global level

$$B(r) + B^*(r) = 0. \tag{1.26}$$

This is the case where asset demand and supply curves of the two countries are on top of each other, similar to the autarky case. In a more realistic case, assume that the two countries apply different capital income taxes and say capital income tax in Home, τ_k is lower. This implies the asset demand curve for Home, $K + D$ lies to the right of the asset demand curve for Foreign. The logic is as follows. For a given world interest rate r, if τ_k is lower r_k is lower and K/N ratio is higher (See equation (21); similar logic applies to Foreign by equation (22); which implies w is higher and hence N is higher. Higher N implies K is higher. For the sake of simplicity and to highlight the effects of fiscal policy, I assume that the initial conditions of the two countries are different only due to the differences in fiscal policy parameters. Hence I assume that Home has a lower capital income tax in the pre-reform steady state.This implies that from the comparative static analysis above, the $K + D$ curve for Home lies to the right of the $K^* + D^*$ curve of Foreign, i.e. the steady-state capital stock in Home is higher due to the lower capital income tax rate.

As a result, there is excess supply of capital in Home and excess demand for capital in Foreign yielding a negative foreign asset position for Home and a positive foreign asset position for Foreign at the equilibrium interest rate, i.e. for a given world interest rate r,

$$B(r) = A(r) - K - D < 0 \tag{1.27}$$

and

$$B^*(r) = A^*(r) - K^* - D^* > 0. \tag{1.28}$$

Therefore, in my model, the global net foreign asset imbalances is mainly a consequence of the cross-country capital tax differences.[12] Cross-country differences in labor income taxes, government expenditures, or public debt stock also cause shifts in these curves and most importantly, the asset supply curves do not necessarily overlap. But as shown in the next section, the properties of the initial steady state equilibrium are qualitatively similar to those mentioned here.

Removing the capital income tax in Home implies that *Home (Foreign)* increases (decreases) its capital stock, *Home*'s (*Foreign*'s) net foreign asset

[12] In Mendoza et al. (2007) for example, global imbalances are modeled as a result of heterogeneity of countries in the degree of their market incompleteness, which is reflected in the cross-country differences between household borrowing constraints.

position deteriorates (improves) and the world interest rate rises due to *Home* tax reform. By the following condition for steady-state aggregate employment from equation (20) above, higher capital stock K implies higher aggregate employment N in the steady state. Higher N in *Home* implies higher output. *Foreign*, on the other hand, suffers a loss of capital stock, lower hours worked and lower output. However, a quantitative experiment is required to see how the government debt stock evolves and the new labor income tax is determined in response to a capital tax cut. In this framework, the post-reform steady state equilibrium allocations are solved simultaneously with the transition path. The next section explains these dynamics in detail.

1.3.1 Numerical solution and calibration

Since the model involves inequality constraints, local approximation techniques are not appropriate to approach the problem at hand. I use a technique called the endogenous grid point method by Carroll (2006), blending the time-iteration method by Coleman (1990) and policy function iteration.[13] I solve the pre and post-tax reform steady states as well as the transitional path based on the endogenous grid point method.

Assuming the post-tax steady state is converged at time T, the post-

[13] Time iteration is a convenient method that can deal with inequality constraints easily. It also relies on interpolation techniques and therefore preserves the continuity of the state space. Coleman (1990) suggests using a root-finding algorithm (a variant of Newton's method) to solve for the decision rules which requires a lot of computing time. Carroll (2006) however, provides a faster method that avoids a nonlinear equation solver. In particular, we only compute the expected marginal utility in the Euler equation and then solve for the current period's consumption algebraically.

reform steady state can be computed once the levels of public debt, D_T and D_T^* are known. These however, depend on their values in the transition, therefore the final steady state and the transition need to be computed simultaneously. First, the pre-reform steady state is computed. Then the post-reform steady state and the transition are computed based on a variant of shooting algorithm. Once the paths of government debt are known for each country, the post-reform labor income tax rates are determined endogenously. In addition, the parameters of government expenditures are determined endogenously. The details of the solution technique are provided in the appendix.

I calibrate the model to match the US and ROW macroeconomic aggregates and wealth distribution (only for the US). ROW consists of Japan, Euro Area, Emerging Asia and Oil Exporting Countries (A complete list of the countries can be found in the appendix). The number of targets to be matched is high compared to the existing literature, and there is little room in the model to match both the aggregates and the distributions. Despite these challenges, the current parameterization is able to match the targets to a great extent.

Preferences and Technology: Benchmark model parameterization is summarized in Table 1.1 below. Accordingly, capital's share in output is 0.36, and the depreciation rate is 0.06. I assume a CRRA utility function with the coefficient of risk aversion is 1, implying log utility. The discount rate is set at 0.965 and the resulting steady state capital-output ratio is 3.40 for the US and 3.27 for the ROW.

	Model		Data
	US (FI)	ROW (FI)	US
Wealth Gini (Pre-reform)	0.76	0.76	0.78
Asset holding distribution			
Top 1%	11.30%	11.31%	29.6%
Top 10 %	59.48%	58.41%	66.1%
Top 20 %	82.52%	81.58%	79.5%
Bottom 40 %	1.43%	1.10%	1.33%

Table 1.1: Distributional properties of the pre-reform steady-state

Borrowing limits: I set them in each country at $\underline{a} = 0$, hence households are not allowed to borrow.[14]

Labor productivity process: These are taken from Domeij and Heathcote (2004) where it is assumed that there are three productivity shock levels, $E = \{\varepsilon^h, \varepsilon^m, \varepsilon^l\}$ with $\varepsilon^h = 4.74$, $\varepsilon^m = 0.847$ and $\varepsilon^l = 0.170$, and identical in both countries. The transition probabilities are given by

$$\Pi = \begin{bmatrix} \Pi_{11} & 1-\Pi_{11} & 0 \\ \frac{1-\Pi_{22}}{2} & \Pi_{22} & \frac{1-\Pi_{22}}{2} \\ 0 & \Pi_{11} & 1-\Pi_{11} \end{bmatrix} = \begin{bmatrix} 0.90 & 0.10 & 0 \\ 0.005 & 0.99 & 0.005 \\ 0 & 0.10 & 0.90 \end{bmatrix}$$

This parameterization yields an endogenous wealth distribution that matches the overall wealth inequality, the Gini coefficient closely in the data (1992).

In the model, the poorest 40% of the U.S. households (under financial integration) hold 1.43% of total wealth and the richest 10% hold 59.48%. As we move towards the right-end of the asset distribution however, the model is

[14]While this is a standard assumption in the literature, I will present results with negative borrowing limits in the next draft.

less able to match the data. However, since it is the wealth-poor households that are most likely to suffer from the reform, matching the left-tail of the asset distribution closely is sufficient to determine the fraction in favor of the reform. On the other hand, since the asset holdings of the rich are underestimated, the potential aggregate welfare gains of the tax reform are underestimated, as well. Since a household will support the reform as long as the household's gain is positive, the relatively weak estimation of the right-tail of the distribution does not affect the analysis on the desirability of the tax reform.

Government policy: I set the U.S. capital and labor income tax at 39.7% and 26.9%, respectively, following Domeij and Heathcote (2004) where they report the average tax rates for the period 1990-1996, based on the methodology of Mendoza, Razin and Tesar (1998).[15] Since these estimates are based on OECD data, the tax estimates are unavailable for many countries in the ROW and calculated only for G7 countries. If I restrict the set of countries to G7, however, the resulting allocations are unable to capture macroeconomic aggregates in the data, especially the U.S. external debt position.[16] Therefore, I set the labor and capital tax rates for the ROW in order to match the global financial imbalances. The capital income tax rate for the ROW is 45% and the labor income tax rate is 22%. Another way of interpreting these taxes is that the institutional imperfections in the ROW are reflected as a wedge on

[15]Landry (2011) updated these estimates for 2009, and the capital and labor income tax for the US are 38% and 22.3%, respectively. I will update my calculations based on the recent estimates in the next draft.

[16]The major foreign holders of U.S. treasury securities in 2012 include Japan, China, emerging Asian countries and oil exporters.

Technology, preferences	α	β	δ	σ	$\underline{a}$	
& borrowing limit	0.36	0.965	0.06	1	0	
Fiscal policy	D/Y	D^*/Y^*	τ^k	τ^{k*}	τ^n	τ^{n*}
	0.66	0.60	0.397	0.45	0.269	0.22

Table 1.2: Parameters in the pre-reform steady state

capital and labor returns.[17] I set D_0 and D_0^* to match the US and ROW public debt-to-GDP ratio (which also determines the government spending-to-GDP ratio, given the tax rates.) These values match the data closely.

The model yields the net foreign asset-to-GDP ratio for the US as -19.5%, which is close to the data reported by Lane and Milesi-Ferretti (2007). These values range between -16% and -20% during 2004-2007. For ROW, the model yields the NFA-to-world GDP ratio of 9.87% which is close to 9.5% observed in 2006. Public debt-to-GDP ratio for the US is 66% while for the ROW is 60%. For the U.S. in 2009, this value was 67% (Central Government Debt from *World Development Indicators*). For the ROW, the data are not reported for several countries and the average public debt-to-GDP ratio is 59% in 2009 for the remaining set of countries. The government spending-to-GDP ratio for the US and ROW is 21.6% and 19.3%, respectively. In 2009, these were 17.5% and 18.8% (average) respectively (Central Government Final Consumption Expenditure from *World Development Indicators).*

[17]See Caselli and Feyrer (2009) and Chen, Imrohoroglu and Imrohoroglu (2009) for similar interpretations.

	Financial integration				Financial Autarky	
	US		ROW		US	
	Initial	Final	Initial	Final	Initial	Final
Capital income tax	0.397	0.00	0.45	0.45	0.397	0.00
Labor income tax	0.269	0.34	0.21	0.22	0.269	0.35

Table 1.3: Tax rates in the pre- and post-reform steady-states

1.4 Results

1.4.1 Macroeconomic consequences of tax reform

I first present the impact of the tax reform on macroeconomic aggregates. When the world economy is in the steady-state, the U.S. capital income tax is replaced by a higher labor income tax. The reform is permanent and unanticipated. The ROW labor income tax also increases in order to recover the loss in tax revenues. The resulting labor income tax rates in the model economies are given in Table 1.3 below.

Figure 1.1 presents the dynamics of economy-wide variables. Consumption, capital and output are given in terms of percentage changes relative to the initial steady state, while all other variables are defined relative to output and therefore their percentage point deviations from the initial steady state are plotted.

The macroeconomic effects of the reform in an open economy differs from the closed economy in three main dimensions: *i) long run gains*, *ii) short run costs*, and *iii) adjustment in labor income taxes.*

i) Long run and ii) short run: The reform stimulates investment and output in the long run in the U.S., and international borrowing enables the rise in these two variables to be greater relative to autarky. The reform also requires U.S. households to sacrifice some of their consumption in the short run: we observe a drastic fall in consumption on impact under both financial integration and autarky. When U.S. households have access to international markets, rising investment can be financed via foreign funds and therefore the transition becomes less painful.

Towards the post-reform steady state, the consumption path recovers and in the post-reform steady state, it reaches to a higher level compared to the pre-reform steady state. The long run gains in the open economy are lower relative to the closed economy. This is because in the long run, the U.S. households service their debt and therefore cut some of their consumption. The U.S. tax reform has major international spillover effects. In particular, ROW suffers an aggregate consumption loss on impact. Their capital stock declines and output falls.

Figure 1.3 plots the external debt dynamics. A capital tax cut in the U.S. causes a sudden deterioration of its net foreign asset position, and the liabilities relative to GDP rise by about 50 percentage points relative to the initial steady state. U.S. net exports decline on impact, and reaches to a higher level in the short run exceeding its pre-reform level. U.S. current account, which can be derived as the difference between aggregate saving and investment, depicts a similar pattern. This implies that global financial imbalances increase

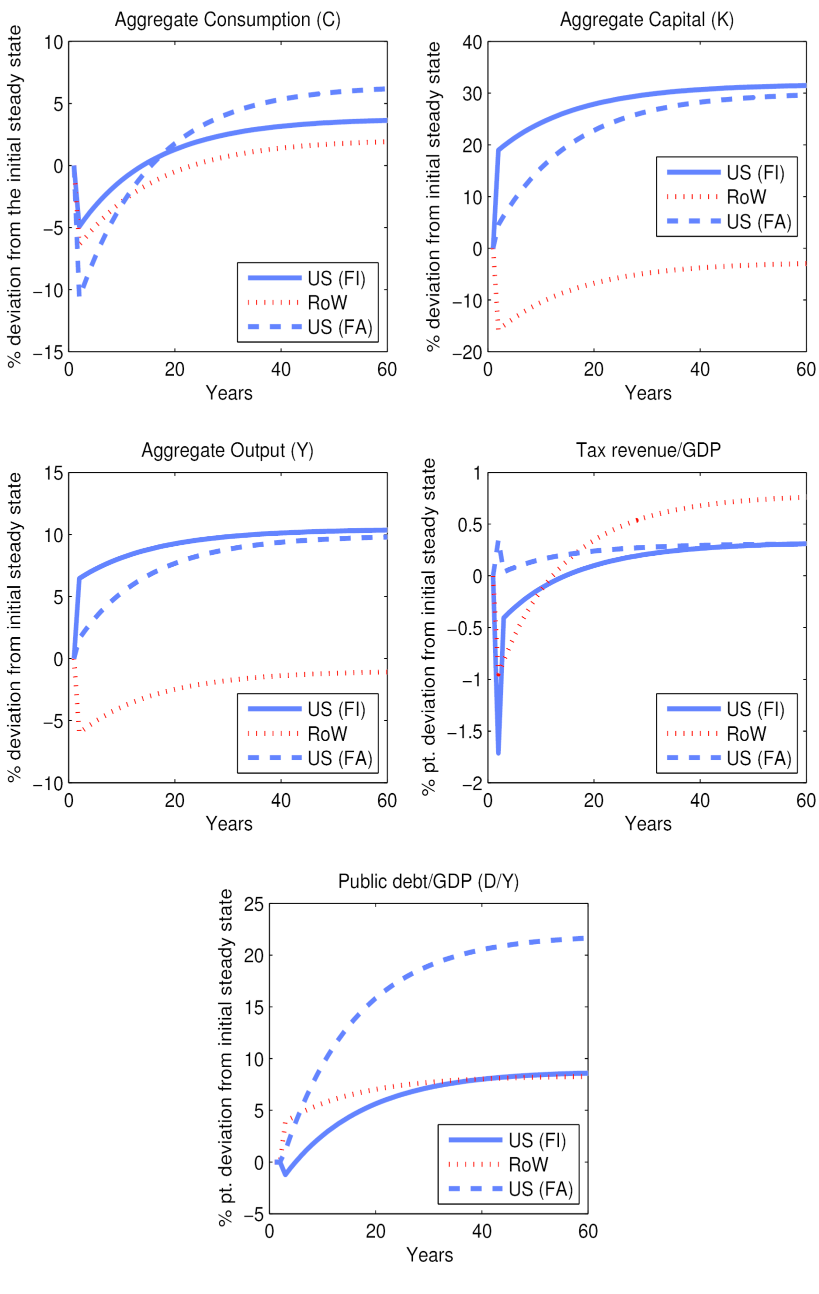

Figure 1.1: Transition dynamics of macroeconomic aggregates

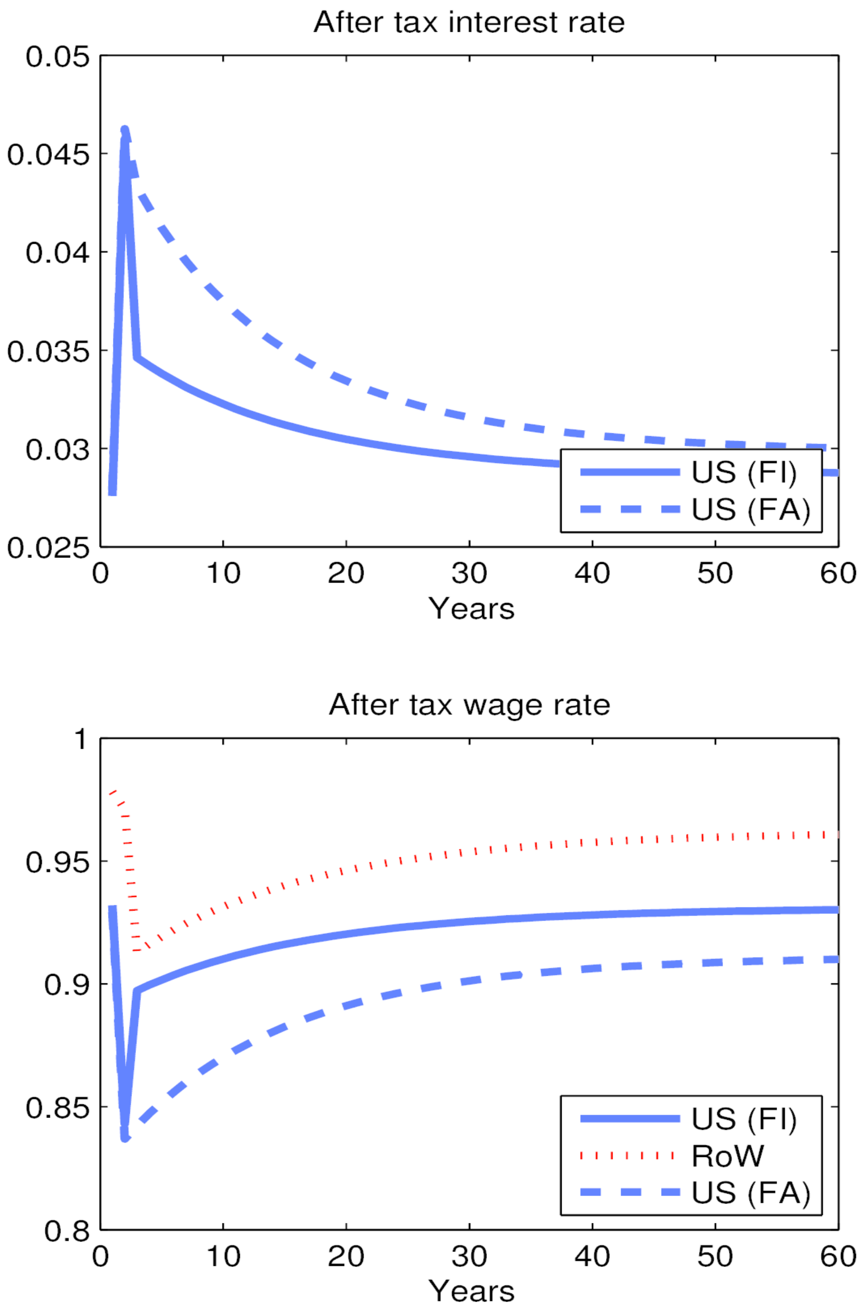

Figure 1.2: Transition dynamics of factor prices

sharply, deteriorating further the external debt position of the U.S. Figure 5 shows the factor price movements.

With the elimination of capital income tax, the world interest rate rises. As capital stock adjusts, the interest rate starts to decline. However, the long run level of the interest rate is higher than the pre-reform level. The rise in the labor income tax creates an initial decline in the after-tax wage rate, and it starts rising as capital accumulation increases. The after-tax wages in the U.S. cannot reach the level of the pre-reform equilibrium. As can be seen in Figure 1.2, the movements of factor prices are smaller in magnitude for the open economy when compared to the closed economy.

iii) Labor income tax adjustment: Since capital income tax is set at 0 under the tax reform, the only source of tax revenue to the government is the labor income. A rise in the capital stock implies that the pre-tax wage rate rises. Given the greater ability to accumulate capital in the open economy, wages rise more and therefore the government needs to raise labor income tax less relative to the closed economy. Table 3 reports these numbers. The implications of the price changes are particularly important for the welfare analyses, and I will continue their discussion in the next session.

Mendoza and Tesar (1998) refer to similar channels in their analysis of tax reforms in the global economy[18] and the qualitative dynamics are similar to a great extent. One major difference between the current framework and

[18] Instead of adjusting the labor tax, they increase the consumption tax.

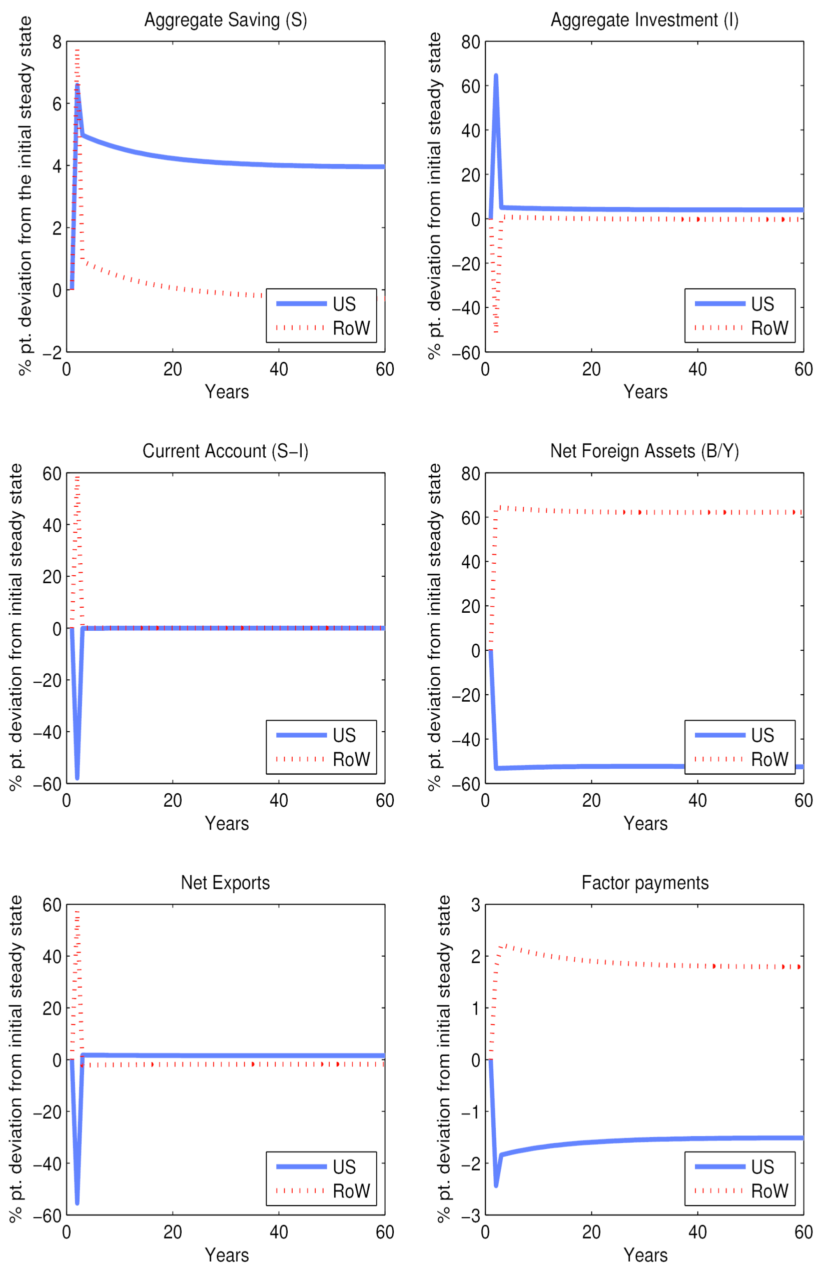

Figure 1.3: Transition dynamics of external accounts

the neoclassical growth model is, however, the long run movements of factor prices. Under the neoclassical paradigm, the steady state interest rate is exogenously determined by the model's parameters, and the reforming country causes changes in the price dynamics only during the transition, while in this model, as a consequence of market incompleteness, it is always endogenously determined.

Macroeconomic dynamics give us an idea about the consequences of the reform and the potential gains and costs. However, as shown in the next section, these gains and costs are not distributed equally for all households.

1.4.2 Welfare consequences of tax reform

Now I look more closely at households and show how their welfare is affected. I also calculate the fractions of population in favor of the tax reform under financial integration and autarky. For this purpose, I simulate a large artificial population of households that match the initial steady state distributions and the wealth distribution observed in the U.S. data. Using the computed equilibrium sequence of interest rates the transition under the reform and the interest rate under the *status quo*, I track the two model economies for many years. I calculate expected welfare gains for households with various initial asset/productivity combinations. More precisely, I compute the consumption equivalent welfare gain for a household with a given state pair

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^{NR}(1 + g(a_0, \varepsilon_0))) = E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^R) \tag{1.29}$$

where c_t^{NR} is the consumption if no reform occurs, and c_t^R is the consumption under the tax reform. Therefore, $g(a_0, \varepsilon_0)$ is the proportional increase in the consumption of a household under *status quo* that would make that household indifferent between going through the reform and remaining in *status quo.* Figure 1.4 below shows the welfare consequences for the U.S. households across different wealth levels under financial integration.

The left vertical axis and the solid line show the consumption equivalent welfare gain of a household with a given level of wealth; and the right vertical axis and the dashed line gives the cumulative distribution function of the households in the U.S. under financial integration. As seen in the graph, households with low asset holdings (the wealth-poor) suffer a negative welfare gain, and as the wealth level increases, welfare gains become positive. The measure of households with negative welfare gains is large when we look at the distribution function on the right axis: 70.83% of the U.S. population. Hence, we conclude that under financial integration, the fraction in favor of the reform is 29.17%.

As discussed earlier, factor price dynamics play an important role in determining who gains and who loses from a tax reform. An increase in the after-tax interest rate benefits the whole population, as the borrowing limit is set at 0, all households are net lenders. Higher interest rate increases the return to their savings and, therefore, increases their ability to do consumption smoothing. Along the transition path and in the long run, the after-tax (world) interest rate rises less under financial integration compared to autarky and the

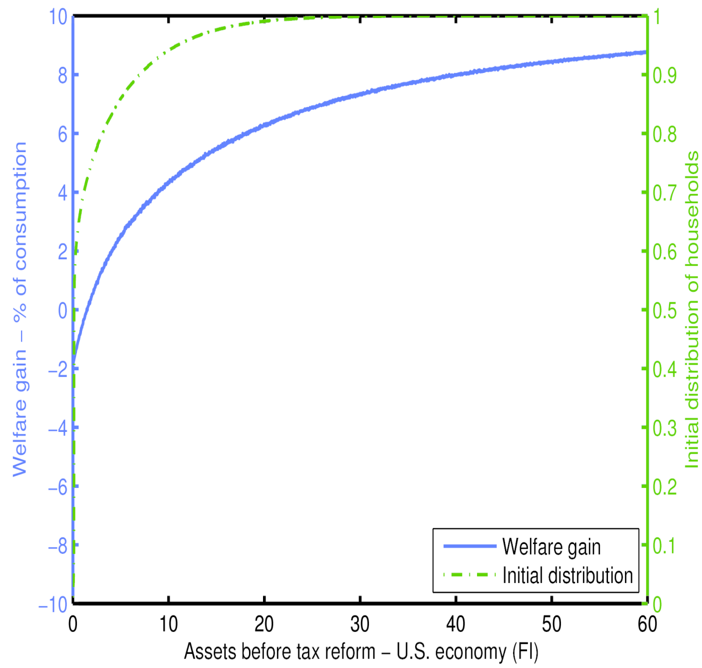

Figure 1.4: Welfare gains across wealth levels (Financial Integration)

gains become smaller. On the other hand, after-tax wage rate declines after the tax reform and the change in the after-tax wage is also smaller under financial integration.

Since the primary source of earnings is labor income for wealth-poor households, a decline in after-tax wage outweighs the gains from an increase in the interest rate, if there are any. Obviously for example, a household that is at the borrowing limit suffers the biggest loss. But the cost is mitigated under financial integration: the wealth-poor are affected less by the negative consequences of the reform under financial openness. Figure 1.5 shows the

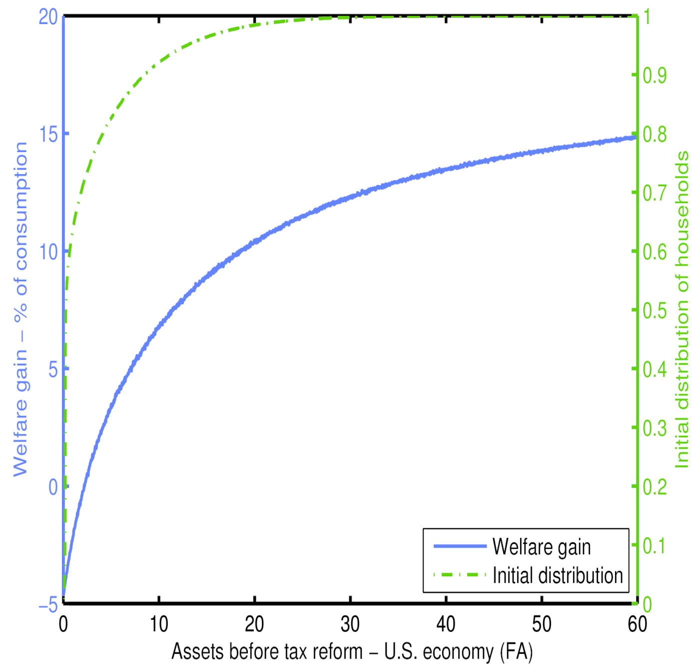

Figure 1.5: Welfare gains across wealth levels (Autarky)

welfare gains of eliminating the capital income tax under financial autarky. The gains and losses are greatly overestimated under financial autarky.

Next, I decompose households according to their initial productivity levels (Figure 1.6). This is important because a household that starts with a high productivity is also more likely to accumulate a high level of assets than a household with low productivity (because productivity shocks are positively correlated with wealth) given that their initial asset levels are the same. Consequently, the household with a high productivity level is more likely to benefit from a capital income tax cut. However, productivity shocks constitute an im-

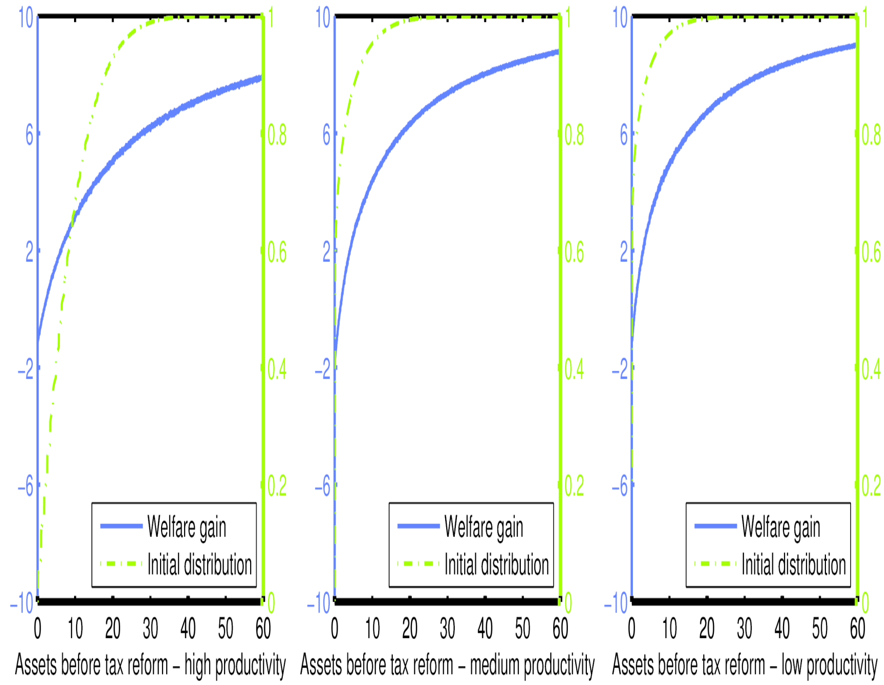

Figure 1.6: Welfare gains across productivity levels (Financial integration)

portant part of the labor income, and high productivity households are also taxed more for their labor income. As a result, there are two opposing forces in assessing the welfare gains for households according to their productivity.

The first panel shows the consumption equivalent welfare gain (%) for households with high productivity shocks prior to the reform. For this group of households, only a small fraction has a negative welfare gain which makes up 29.17% of the high-productivity group. The majority of the high productivity households support the reform. For medium and low productivity households, however, the fraction in favor is smaller: 26.55% and 24.54%, respectively.

	Financial integration	Autarky
Fraction in favor	29.17%	26.08%
High productivity group	86.15%	80.26%
Medium productivity group	26.55%	23.62%
Low productivity group	24.54%	20.97%

Table 1.4: Fraction in favor of tax reform

Given that the high productivity households have a small measure in the U.S. population, the reform is not favored by a majority -as shown in Figure 1.4 earlier.

When the U.S. is modeled as a closed economy however, the fraction in favor of the reform is underestimated. Table 1.4 compares the results under two models below.

Table 1.4 shows that a closed economy model underestimates the fraction in favor of the reform by 3.09% compared to the open economy. Similar differences can be observed when we look at the three different groups, the major difference being in the high productivity group, with 5.89%.

I also compute the aggregate welfare effect of the reform to the economy assuming an utilitarian social welfare function in which a benevolent social planner assigns equal weight to all households in the U.S. The aggregate welfare gain is computed as the proportional increase in the consumption of all agents under *status quo* that makes the planner indifferent between remaining in the *status quo* (with the consumption increase) and implementing the tax reform. In this aggregate welfare measure, the percentage increase in consumption

	Financial integration	Autarky
Aggregate gain	-0.24%	-1.55%
SS gain	2.16%	3.69%
Transitional cost	-2.45%	-5.14

Table 1.5: Aggregate welfare gain

is the same for all agents within each country. Therefore, this is also the percentage increase in aggregate consumption. More precisely, the aggregate welfare gain for a country is defined as g^A that solves

$$\int_{(a_0,\varepsilon_0)} E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^{NR}(1+g^A))d\Gamma_0 = \int_{(a_0,\varepsilon_0)} E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^{R})d\Gamma_0 \tag{1.30}$$

Table 1.5 summarizes the results. The reform is costly and through financial openness, the aggregate welfare loss is 84.5% smaller relative to autarky. Steady state gains are smaller, as servicing debt requires consumption losses as discussed earlier. However, international borrowing reduces the transitional cost to a great extent. The net gain is -0.24% under financial openness.

1.5 Conclusion

I analyze the macroeconomic and welfare consequences of eliminating the U.S. capital income tax unilaterally under financial integration with heterogeneous agents and incomplete markets. The labor income tax is raised to maintain fiscal solvency. The reform stimulates investment and output which are expanded further by capital inflows from abroad; it also provides welfare gains to the U.S in the long run. These positive consequences are accompanied with sizable fiscal and financial imbalances and transmitted to the rest of the world resulting in welfare losses abroad on impact.

The cost of transition to the reformed steady state is reduced to the extent that U.S. households can borrow from abroad. However, under a realistic calibration of the model the short run costs exceed the gains. The net cost is 84.5% smaller than the predictions of a closed economy, heterogeneous agent-incomplete markets model.

The costs and gains of reform are not shared equally across households. Wealth-poor households that primarily rely on labor income lose due to a labor tax raise while not gaining much from a capital income tax cut. The wealth-rich, on the other hand, enjoy welfare gains. International capital flows help alleviate the costs of the reform to the poor; while reducing the gains to the rich. This is due to the dynamics of factor prices. Given the high wealth inequality in the U.S., the reform is not supported by the majority of population.

My final comments are related to the literature on market incompleteness and efficiency. Providing households with insurance against idiosyncratic risk is an obvious yet difficult way to improve welfare. Therefore, government policy can be justified as one way of improving welfare. Dávila, Hong, Krusell and Ríos-Rull (2012) suggest that taking as given the environment with uninsured idiosyncratic labor income risk, it may be constrained optimal to *subsidize* capital.

In this paper, I do not draw conclusions on what the optimal tax or subsidy on capital should be under market incompleteness. However, my findings show that, as far as a capital income tax cut is concerned, the negative effects of market incompleteness are mitigated to a great extent by international capital flows. Financial globalization can be interpreted as a natural mechanism that improves welfare. Since the world economy is in fact financially integrated, issues on optimal or constrained optimal taxation should be investigated through the lens of financial openness.

Chapter 2

What helps forecast US inflation?-Mind the gap!

[1]

2.1 Introduction

Forecasting inflation—accurately and reliably—plays a critical role for policy-making and for the decisions of the private sector in making long-term nominal commitments. In macroeconomic analysis and inflation forecasting, the traditional Phillips curve has been a widely used model that captures broadly the empirical relationship between inflation and unemployment rate, capacity utilization or output gap.

As documented by Atkeson and Ohanian (2001), the Phillips curve has flattened since 1984. Their finding was that the Phillips curve-based models did not yield more accurate forecasts than the naïve, 4-quarter random walk benchmark. Stock and Watson (2007) emphasized the role of lower volatility in inflation in the U.S. and in the world in this period. Hence the risk of naive forecasts, computed as the mean square forecast error, declined. Forecasts under a Phillips curve specification have become less accurate. A survey by Stock

[1] This essay is drawn from the joint work with Enrique Martinez-Garcia.

and Watson (2008) suggest recent forecasts based on univariate specifications including the Phillips curve performed well only occasionally.

A prominent explanation to the break in the Phillips curve suggested in the literature is globalization - the integration of global markets in goods, labor and capital. The recent literature postulated the 'global slack hypothesis', i.e. foreign slack as well as domestic slack drives inflation in the short-run. Hence, a more relevant specification, the open economy Phillips curve that ties inflation to global measures of economic activity has become a focus of investigation. However, the evidence on the role of global slack is mixed. Binyamini and Razin (2007) and Martinez-Garcia and Wynne (2010) made theoretical explanations and Borio and Filardo (2007) provided empirical evidence for the global slack hypothesis. On the other hand, Milani (2010, 2012) among others, argue that the foreign economic activity has a role on domestic supply and demand, but its effect on domestic inflation is negligible, finding weak evidence for the global slack hypothesis.

Even when the theoretical validity of an open economy Phillips curve is assured, forecasting inflation under the open economy framework is a challenging task. It is in general difficult to find sufficiently long, reliable and robust time series of global slack -global output gap or capacity utilization. This has been documented in the current paper as well as in previous studies. Therefore, it gains particular importance to evaluate forecast accuracy with various global slack measures and to compare their performances to those from alternative measures.

In this paper, we test whether global slack measures have predictive power for U.S. inflation. These measures are constructed by mostly theoretically-consistent output gap or capacity utilization series of the U.S. and several different groups of countries combined. In addition, following a recent theoretical finding in Martinez-Garcia and Wynne (2010), we test the performance of a global slack measure defined as a combination of two variables: domestic slack and terms of trade gap. The measure of terms of trade gap is HP-filtered terms of trade, while the domestic slack series are the U.S. measures of output gap, capacity utilization and HP-filtered GDP.

Our first finding is that, perhaps in agreement with the existing literature, these global slack variables yield mixed results in predicting different inflation measures. However, a striking result in this paper is that the terms of trade gap, alone, is a good forecasting variable for U.S. inflation. It yields more accurate forecasts relative to the naive autoregressive process of inflation and it is also robust to various forecast horizons, inflation measures and estimation samples, including the late 1980s –the period of break in the Phillips curve pointed out by Atkeson and Ohanian (2001). On the other hand, we document that most global slack measures yield relatively more accurate forecasts for core inflation while the forecast with terms of trade gap and domestic slack perform well at short horizons for headline inflation measures. Overall, the forecasting performances are not very robust to forecast horizons and estimation samples.

We conduct pseudo out-of-sample forecasts for six measures of U.S. inflation at horizons varying between 1-quarter to 12-quarter ahead. Our benchmark estimation and sample periods are 1980:1-1991:4 and 1992:1-2011:4, respectively. For robustness analyses we go back as far as to 1949:1 and perform rolling forecasts, to the extent that data series are available. Our metric for forecast accuracy is the mean square forecast error (MSFE) of a reduced form new open economy Phillips curve with distributed lags of inflation and slack, relative to the MSFE of the 'restricted' forecast described as a univariate, autoregressive process of inflation. We compute bootstrap standard errors for the MSFEs following Clark and McCracken (2006).

Another major contribution of this paper is our extensive robustness analyses where we compare the performance of a selected measures of slack to a set of widely used variables in the forecasting literature. We test the predictive performances of a domestic slack series (CBO U.S. slack), a global slack series (OECD Total slack), a measure of domestic liquidity growth (U.S. M2 growth) and global liquidity growth (G7 average of monetary aggregates) and two variables of terms of trade gap (HP-filtered U.S. terms of trade, and HP-filtered U.S. terms of trade ex. oil). We report the following stylized facts:

- Forecasts with the domestic slack perform significantly better than the simple AR process of inflation until late 1960s and particularly at short horizons. The global slack measure outperforms the simple AR process significantly only in late 1980s and at short horizons.

- In episodes where domestic liquidity growth performs well in forecasting

U.S. inflation, global liquidity growth does not; and vice versa. This result is in general robust to several inflation measures and horizons for the rolling forecasts starting in 1963 through early 1980s. After that period, the relative MSFEs of the forecasts are insignificant for both variables.

- Forecasts with HP-filtered terms of trade perform significantly better relative to the naïve forecast with the estimation samples starting in 1950s till late 1980s (with the exception in 1980-1983, where the performance deteriorates). At some occasions where terms of trade performs relatively weak, terms of trade ex. oil does significantly better.

Therefore, we show that many conventional alternatives do not improve upon the naïve forecast especially in recent years, while HP-filtered terms of trade stands out as a relatively successful variable.

In the remainder of the paper, we try to understand these patterns in the light of a workhorse New Open Economy Macroeconomics (NOEM) model. Our strategy is to use a model that can capture the effects of two other competing (or complementary) hypotheses in addition to globalization –good luck and good monetary policy - that are commonly discussed in the literature as plausible explanations for the observed strengths and weaknesses in the forecasting performances. To this end, we simulate data based on the model and use the data to conduct forecasts similar to those in the empirical section. We estimate MSFEs for many plausible parameter values that capture changes in trade openness, volatility in TFP or monetary shocks (which we call 'good luck') and effectiveness of monetary policy reflected in Taylor rule parameters.

For most of these patterns of forecast accuracy, we find monetary policy and good luck seem to be the two important channels, while openness has a secondary role on forecast accuracy.

2.2 Methodology

2.2.1 Data

Figure B1 plots the series employed throughout the paper. The U.S. inflation rate is calculated as annualized log-differences of quarterly series of six price indices: consumer price index (CPI), core CPI (CPI ex. food and energy), personal consumption expenditure deflator (PCE), trimmed-mean PCE, GDP deflator and producer price index (PPI).

We perform inflation forecasts using a wide range of domestic and global slack measures. Our domestic measures consist of CBO U.S. slack, FRBD U.S. slack, OECD U.S. slack, IMF U.S. slack and HP-filtered U.S. real GDP. For global slack measures, we use FRBD G7, FRBD G39, OECD G7, OECD Total and IMF Advanced series. All series are available quarterly, except for the IMF measures of domestic and global slack, which is available in annual frequency. We therefore disaggregate these series into quarterly frequency using quadratic match average.

Terms of trade series is calculated as the ratio of U.S. export price index of goods and services and U.S. import price of goods and services. For terms of trade ex. oil, however, we use the price indices for exported goods and nonpetroleum imported goods due to limited data availability. We HP filter these two series in order to obtain a measure of the terms of trade gap.

We define global money growth as the average of the percentage growth rates of broad money stock in G7 countries. While we pick the series for monetary aggregates that are most similar in definition, we are constrained by quarterly data availability for Canada, France, Germany, Italy and Japan particularly for late 1960s or early 1970s. Since we would like to extend the robustness analysis of forecasting experiments to a large estimation sample, we make our primary decision on selection based on data availability. Therefore our series start in the second quarter of 1963 and we use M2 for U.S., M4 for UK. We splice two short series of M3 for Canada, M2 for Germany, Italy and Japan. For France, we also use a spliced series, which combines M2R up to the first quarter of 1970 and M3 afterwards. (A more detailed explanation is available in the appendix.)

2.2.2 Models

We specify three models to forecast inflation. Following Stock and Watson (2003), we refer the models with explanatory variables as economic models and we assess to what extent these economic models represent an improvement over the univariate model of forecasting inflation. The first model is a univariate model where we test the predictive power of various regressors.

Stock and Watson (1999a, b, 2008) provide some empirical evidence in favor of the Phillips curve as a forecasting tool, suggesting that inflation forecasts produced by the Phillips curve generally are more accurate than forecasts based on other macroeconomic variables (including interest rates, money and commodity prices). Consider first the traditional backward-looking Phillips curve relating inflation to aggregate real economic activity as typically specified by the previous literature

$$\hat{\pi}^h_{t+h|t} = a_1 + \lambda_{11}(L)\hat{\pi}_t + \lambda_{12}(L)\hat{x}_t + \hat{\epsilon}_{1,t+h} \qquad \text{(Model 1)}$$

Denoting the quarterly forecast horizon by h, it is possible to forecast h-quarter ahead inflation, $\hat{\pi}^h_{t+h|t}$ with the distributed lag of earlier inflation rates, $\hat{\pi}_t$ as a proxy for expected inflation, and the distributed lag of the domestic slack measure, $\hat{x}_t$. We start with assessing the predictive performance of domestic slack in order to compare our results with those of the earlier studies using this specification in the literature. We define h-quarter ahead (annualized) inflation $\hat{\pi}^h_{t+h|t} = \frac{400}{h} \times [log(P_{t+h}/P_t)]$ and forecast inflation for horizons ranging from 1 quarter-ahead to 12-quarters ahead. The number of lags for each variable is selected based on SIC. To keep the model parsimonious and since the frequency of the variables is defined as quarterly, the maximum possible lags allowed for each variable is set as four.

As the global financial integration substantially increased in the past 30 years, its consequences on inflation, and the consequences of foreign economic activity in particular, has become a focus of attention in inflation forecasting. Martinez-Garcia and Wynne (2010, 2012), among others argued that the Phillips curve on economies open to trade depends on global economic activity and leading or contemporaneous predictors of domestic inflation should include not just domestic but foreign economic activity. We therefore include global measures of slack—as well as domestic slack—among our representative series. Hence, we test the predictive performance of global slack measures in an open economy Phillips curve, similar to the one specified above, where $\hat{x}_t$ is now defined as global slack.

We further evaluate the performance of other variables such as domestic and global liquidity growth[2] and terms of trade gap measures under the same framework. While the long-run relationship between the growth rate of monetary aggregates and the rate of inflation is established by the quantity theory of money and therefore testing the forecasting performance of liquidity growth has analytical content, we test the performance of terms of trade gap measures in light of the theoretical results in Martinez-Garcia and Wynne (2010). We perform these forecasting exercises here to readdress the role of these measures in order to provide with a comparison with our main forecasting strategy and also to make an extensive robustness analysis of the earlier work.[3]

[2]D'Agostino and Surico (2009a) evaluate the forecasting performance of the average growth rate of broad money in G7 economies and find that the results are significantly more accurate compared to forecasts with US money growth.

[3]Stock and Watson (1999) forecast U.S. inflation with a large set of variables, including economic indicators other than the variables of real economic activity. These include U.S. effective exchange rate and a number of foreign exchange rates. They report that exchange

The issue of how to measure the output gap—both domestic and foreign—has been known as a major challenge. For purely statistical approaches, which in most cases derive potential output using actual (real) output series through a filtering technique (most commonly the HP filter), the choice of the filter is usually an arbitrary decision. In addition, applying these techniques are known to create end-point problems. For structural estimates of the output gap, relying on a production function (such as Cobb-Douglas) and quantifying the total factor productivity, the capital stock or labor employed tend to pose measurement problems (Gerlach, 2011).

Measuring the foreign output gap, however is an even more challenging task since for the emerging market economies that are believed to potentially affect the U.S. inflation, the data series to measure unemployment rates or capacity utilization in manufacturing are usually either too short or they are not available. Furthermore, there is also not a clear idea on how the dynamics of foreign output gap affects the domestic inflation. Therefore, estimating the open-economy Phillips curve based on the combination of domestic and foreign slack as a measure of the global slack becomes a difficulty.

To circumvent the problem of measuring the foreign slack, we follow the theoretical approach taken in a previous work by Martinez-Garcia and Wynne (2010) and define global slack in reduced form as a combination of domestic slack and terms of trade gap. To estimate this new formulation of the open-

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rates do not yield better inflation forecasting performance than a Phillips curve specification.

economy Phillips-curve, we follow the literature, and take a backward-looking approach for the reduced-form estimate of the curve. The regression equation in this case can be described as an autoregressive distributed lag model which is our first model to forecast inflation:

$$\hat{\pi}^h_{t+h|t} = a_2 + \lambda_{21}(L)\hat{\pi}_t + \lambda_{22}(L)\hat{x}_t + \lambda_{23}(L)\hat{z}_t + \hat{\epsilon}_{2,t+h} \qquad \text{(Model 2)}$$

Under this specification, $\hat{x}_t$ denotes one of the domestic output gap measures and $\hat{z}_t$ denotes one of the terms of trade gap measures (all variables in levels).

Having suggested two different 'unrestricted' reduced-form models, we finally introduce the 'restricted' model. Under this specification, we estimate a univariate autoregressive (AR) process:

$$\hat{\pi}^h_{t+h|t} = a_3 + \lambda_3(L)\hat{\pi}_t + \hat{\epsilon}_{3,t+h} \qquad \text{(Model 3)}$$

2.2.3 Forecast scheme

We perform forecasts based on the pseudo out-of-sample forecasting method and particularly focus on recursive samples. Therefore, at any given date t, we forecast inflation at date $t+h$ using all available data up to date t. The models are estimated by OLS.

We assess the multi-step pseudo out-of-sample forecasting performance of a model that incorporates the variables commonly thought as contemporaneous or leading indicators of inflation relative to the forecast of a univariate autoregressive process. Our forecast evaluation metric, the relative MSFE, is the ratio of MSFE of the economic model (Model 1 or Model 2) relative to that of the benchmark AR model (Model 3). Let T_0 denote the starting date of the data series and T_1 denote the end. The estimation sample starts at T_0 and ends in t_0. We start by using all data up to date t_0 to forecast inflation at date $t_0 + h$. By adding data to the estimation sample, we keep estimating the parameters of the model of interest. The $h-$step recursive forecast continues until period $T_1 \ - h$ with a total of $T_1 - h - t_0 + 1$ steps. For a given model j, this procedure yields a sequence of forecast errors which helps us construct the MSFE of the model at horizon h and from date t_0 to $T_1 \ - h$

$$MSFE_j(h) = \frac{1}{T_1 - h - t_0 + 1} \sum_{t=t_0}^{T_1 - h} \hat{\hat{\epsilon}}^2_{j,t+h}$$

2.2.4 Inference and samples

Inference is based on the F-statistics against critical values based on a bootstrap algorithm described in Clark and McCracken (2006).[4] This procedure involves resampling from the residuals of a vector autoregressive (VAR) equations. In order to test the predictive ability of a single variable forecast as in Model 1, we define an equation for inflation (as governed by the restricted model) and an equation for the predicting variable, where the lag

[4]The construction of F-statistics as well as t-statistics are described in Clark and McCracken (2001, 2002a, b). Inference can also be based on t-statistics, however, as Clark and McCracken (2001, 2002a, b) suggest, F-type tests are more powerful than the corresponding t-type tests and therefore we focus on F-statistics only.

length for the predicting variable and inflation is determined based on SIC. The equations of the data generation process (DGP) are estimated by OLS with a number of bootstrap iterations equal to 5000. For a bivariate forecast involving an additional predicting variable as in Model 2, we suggest a similar methodology. In this case, the DGP involves the estimation of a 3-equation VAR. The first equation is the AR process of inflation, as defined in the bootstrap algorithm of the univariate forecast. The remaining two equations are the equations for the predicting variables where we include the lagged values of all three variables (inflation and two predicting variables) as regressors in each equation. Again, the lag length selection is based on SIC. We have a one-sided test with the null hypothesis that an economic model (Model 1 or 2) does not yield more accurate forecasts than the AR process (Model 3), i.e. $MSFE_{AR} \leq MSFE_{EM}$, against the alternative $MSFE_{AR} > MSFE_{EM}$. Throughout the paper, we report the MSFE of the benchmark model and the relative MSFEs of a particular economic model and the benchmark. The null hypothesis is expressed as 'the relative MSFE is greater than or equal to 1'. We report the p-values of the F-test at 1%, 5% and 10% significance levels.

In our benchmark experiments, the estimation sample begins in the 1980:Q1 and ends in 1991:Q4 and the pseudo out-of-sample forecasting period begins in 1992:Q1 and 2011:Q4 leaving us with an estimation sample of 48 quarters and the pseudo out-of-sample forecasting sample of 80 quarters).[5]

[5] Our selection of the size of the estimation and pseudo out-of-sample forecasting samples in the benchmark experiments follow that of D'Agostino and Surico (2009) which enables

In addition to our benchmark forecasting experiment, we conduct a series of other experiments going back in time to the extent that the series are available in order to make a robustness analysis. More specifically, starting with the initial observation in the sample, we shift the estimation and forecast samples backward by one quarter and obtain the relative MSFEs of the forecasts for each rolling window.[6] Each window spans 48 quarters of an estimation sample and 48 quarters of a forecasting sample.

Finally, in order to gain insight about our findings and our potential explanations for them, we also run forecasts with the simulated data consistent with the model in Martinez-Garcia and Wynne (2010). Under various parameterizations of the model, we try to understand how factors such as trade openness, the stance of monetary policy towards inflation and the size of the monetary and productivity shocks to the economy affect the predictive ability of these variables. The forecast scheme for this group of experiments is also recursive.[7] We discuss the details of these experiments in section 4.

2.3 Empirical Findings

The results of the pseudo out-of-sample forecast with one variable over the benchmark sample are reported in Tables B1 and B2; while the results

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us a comparison of the measures used to forecast inflation with their measures of money. In our robustness analyses we make a symmetric allocation of the observations for the two samples.

[6] The starting dates are provided in more detail in the appendix.

[7] The bootstrap procedure for the F-test in these experiments involves 500 iterations.

with two variables are summarized in Tables B3 and B4. Our findings can be listed as follows:

1. Based on the one-variable forecast results, it is not possible to say that global slack measures outperform the domestic slack measures. In general, both measures almost equally yield more accurate predictions compared to an AR process when the inflation measure is core CPI and trimmed mean PCE. For other measures of inflation however, we conclude that the AR process of inflation performs better.

2. Global money growth (measured as G7 average) exhibits a better forecasting performance relative to U.S. money growth, at all horizons for CPI, core CPI and PCE deflator. Both variables have a significantly poor performance compared to the AR process in all other inflation measures. Under the forecasts of CPI and PCE inflation, G7 money growth does also better compared to domestic or global slack measures. However, this is not true for the other measures of inflation.

3. Forecasting performance of terms of trade (HP-filtered) is comparable to those of domestic and global slack measures. Terms of trade ex. oil has no significant improvement over the AR specification across any of the inflation measures and at any horizon.

4. Our results of the two-variable forecasts are rather mixed. Forecasts with domestic slack and terms of trade provide higher accuracy at short

horizons for CPI and PCE compared to the forecasts with domestic or global slack alone. For GDP deflator and core CPI, one-variable forecasts do better. When domestic slack and terms of trade ex. oil are evaluated, it can be concluded that the two variables combined improve forecasting performance for GDP deflator especially at short horizons and for PPI at long horizons. Results with two-variable forecasts using domestic or global money growth measures in addition to terms of trade or terms of trade ex. oil, do not improve the predictions.

We perform rolling window experiments for three groups of variables: a domestic slack measure vs. global slack measure; terms of trade vs. terms of trade ex. oil and finally domestic vs. global liquidity growth. Among several alternatives, we choose CBO measure as the domestic slack variable and 'OECD Total' as our global slack measure. Our selection of the two measures is based mainly on the length of the series and relatively better performance compared to other slack measures at hand. In Figures 2a-4b, we show how the forecasting performances of these pairs of variables evolve over time. In these figures, several interesting points emerge:

5. The predictive ability of money growth measures vary significantly over time (Figures B.2-3). In particular, we observe a pattern such that whenever domestic money growth has a poor performance, global money growth performs well and vice versa. During late 1970s, there is a remarkable deterioration in the forecasting power of global money growth,

which is outperformed by domestic money growth especially in long-horizon forecasts. After this period, forecasting ability of global money growth recovers rapidly although its performance compared to the AR process is not necessarily superior. This is interesting, because our empirical results based on the benchmark sample are in line with those in D'Agostino and Surico (2009) where they analyze the 1990:1-2006:2 period and show that global money growth-based forecasts seem to be a strong forecasting variable relative to domestic money as well as the naive forecasts of inflation. However, these results do not seem to be robust to sample selection after 1980s as shown in Figures B.2-3.

6. For slack measures however, and with limited data availability, the patterns mentioned above can no longer be pronounced (Figures B.4-5). Our comparison of domestic and global slack measures show that the predictive power of the two measures move almost together through time, and with rare occasions they become significantly more powerful than the AR process in forecasting inflation. In forecasts starting from 1949 through 1970s (where global slack measures are not available) the CBO measure of U.S. slack has a significantly better performance than the AR specification, especially at short horizons.

7. Terms of trade and terms of trade ex. oil produce a similar (albeit slightly weaker) 'switching' pattern in terms of forecasting performance over time (Figures B.6-7). Except for core measures of inflation (core CPI

and trimmed mean PCE, which are also relatively short series), terms of trade yields significantly more accurate forecasts starting in late 1950s through mid 1970s and its performance deteriorates in general during late 1970s. The MSFEs of the forecasts with terms of trade ex. oil follow a not so uniform pattern and shows a great variability in performance across horizons or inflation measures while outperforming terms of trade at certain intervals. Particularly for the 1980s however, terms of trade and terms of trade ex. oil appear to be doing better in forecasting inflation compared to monetary aggregates or output gap measures.

In the next section, we aim to investigate the causes behind these puzzles. First, we would like to understand why domestic and global slack measures do not perform well and global money growth comes out as a superior measure to forecast U.S. inflation. Second, and related to the previous puzzle, we are not clear as to why domestic slack measures along with terms of trade (or terms of trade ex. oil) do not improve forecasting accuracy as much as expected. Third, in theory, we would expect the HP-filtered slack measures to perform not as great as the slack measures that are calculated with a production function approach.

2.4 Interpreting the results

In order to understand the empirical results more clearly, we simulate the model in Martinez-Garcia and Wynne (2010) which is a variant of the New Open Economy Macro model of Clarida, Gali and Gertler (2002). We briefly mention the building blocks of this model.

2.4.1 The New Open Economy Macro Model

There are two countries, Home and Foreign. The current model consists of three basic structural equations for each country and two exogenous shocks. We denote Foreign variables with an asterisk (*). To denote the deviation in logs from its steady state, $\hat{v}_t \equiv \ln(V_t/V)$, for a variable V_t at its steady state V. Similarly, we denote the deviation of the potential (or frictionless) value of a variable from its steady state as $\hat{v}_t^n \equiv \ln(V_t^n/V)$.

Aggregate demand is described by an equation that links the output gap, $\hat{x}_t$ to domestic and foreign interest rates, $\hat{\imath}_t$ and $\hat{\imath}_t^*$, natural rates $\hat{\imath}_t^n$ and $\hat{\imath}_t^{n*}$, and inflation $\hat{\pi}_t$ and $\hat{\pi}_t^*$

$$\gamma(2\xi-1)(E_t\hat{x}_{t+1}-\hat{x}_t) \approx [((2\xi-1)+\Gamma)[(\hat{\imath}_t-\hat{\imath}_t^n)-E_t\hat{\pi}_{t+1}]-\Gamma[(\hat{\imath}_t^*-\hat{\imath}_t^{n*})-E_t\hat{\pi}_{t+1}^*] \tag{2.1}$$

Aggregate supply is defined as a Phillips curve relating inflation gap to domestic and foreign output gaps

$$\hat{\pi}_t \approx \beta E_t\hat{\pi}_{t+1} + \Phi\left[(\varphi\xi+\Theta\gamma)\hat{x}_t + ((1-\xi)\varphi + (1-\Theta)\gamma)\hat{x}_t^*\right] \tag{2.2}$$

As shown in a previous work by Martinez-Garcia and Wynne (2010), under the producer currency pricing (PCP) assumption, it is possible to express the dynamics of the domestic (cyclical) inflation, $\hat{\pi}_t$, in terms of the domestic output gap, $\hat{x}_t$ and the terms of trade gap, $\hat{z}_t$

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \Phi[(\varphi + \gamma)\hat{x}_t + \Psi_{\pi,z}\hat{z}_t] \tag{2.3}$$

Monetary policy rule is expressed à la Taylor (1993)

$$\hat{\imath}_t \approx \rho_i \hat{\imath}_{t-1} + (1 - \rho_i)[\Psi_\pi \hat{\pi}_t + \Psi_x \hat{x}_t] + \hat{m}_{t.} \tag{2.4}$$

Domestic money growth is derived by first differencing the ad hoc log-linear *money demand* equation

$$\Delta \hat{l}_t \approx \Delta \hat{y}_t - \eta \Delta \hat{\imath}_t + \hat{\pi}_t. \tag{2.5}$$

We also define the natural interest rate as the weighted average of expected domestic and foreign productivity growth,

$$\hat{\imath}_t^n \approx \left(\frac{1+\varphi}{\gamma+\varphi}\right) \left[\Theta_{i,a} E_t[\Delta \hat{a}_{t+1}] + \Theta_{i,a^*} E_t[\Delta \hat{a}^*_{t+1}]\right] \tag{2.6}$$

the potential output as the weighted average of domestic and foreign productivity gap,

$$\hat{y}_t^n \approx \left(\frac{1+\varphi}{\gamma+\varphi}\right) [\tilde{\lambda}_a \hat{a}_t + \tilde{\lambda}_{a^*} \hat{a}^*_t] \tag{2.7}$$

output gap,

$$\hat{x}_t = \hat{y}_t - \hat{y}_t^n$$

and finally terms of trade and terms of trade gap,

$$\widehat{tot}_t \approx \frac{\gamma(\hat{y}_t - \hat{y}_t^*)}{\sigma\gamma - (\sigma\gamma - 1)(2\xi - 1)^2} \text{ and } \hat{z}_t \equiv \widehat{tot}_t - \widehat{tot}_t^n \tag{2.8}$$

respectively. For Foreign, the equations of the model can be described symmetrically.

Finally, the law of motion for productivity shocks and monetary shocks is governed by

$$\begin{pmatrix} \hat{a}_t \\ \hat{a}_t^* \end{pmatrix} \approx \begin{pmatrix} \delta_a & \delta_{a,a^*} \\ \delta_{a,a^*} & \delta_a \end{pmatrix} \begin{pmatrix} \hat{a}_{t-1} \\ \hat{a}_{t-1}^* \end{pmatrix} + \begin{pmatrix} \hat{\varepsilon}_t^a \\ \hat{\varepsilon}_t^{a*} \end{pmatrix} \tag{2.9}$$

$$\begin{pmatrix} \hat{\varepsilon}_t^a \\ \hat{\varepsilon}_t^{a*} \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_a^2 & \rho_{a,a^*} \\ \rho_{a,a^*} & \sigma_a^2 \end{pmatrix} \right) \tag{2.10}$$

$$\begin{pmatrix} \hat{m}_t \\ \hat{m}_t^* \end{pmatrix} \approx \begin{pmatrix} \delta_m & 0 \\ 0 & \delta_m \end{pmatrix} \begin{pmatrix} \hat{m}_{t-1} \\ \hat{m}_{t-1}^* \end{pmatrix} + \begin{pmatrix} \hat{\varepsilon}_t^m \\ \hat{\varepsilon}_t^{m*} \end{pmatrix} \tag{2.11}$$

$$\begin{pmatrix} \hat{\varepsilon}_t^m \\ \hat{\varepsilon}_t^{m*} \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_m^2 & \rho_{m,m^*} \\ \rho_{m,m^*} & \sigma_m^2 \end{pmatrix} \right) \tag{2.12}$$

where the composite parameters are given by

$$\Phi \equiv \frac{(1-\alpha)(1-\beta\alpha)}{\alpha}$$

$$\Psi_{\pi,z} \equiv -\sigma(1-\xi)(\varphi+\gamma) + (\sigma - \frac{1}{\gamma})(\xi - \xi^*)(\varphi(1-\xi)(\eta-\eta^*) - \gamma(1-\eta))$$

$$\Gamma \equiv (1-\xi)\left[\sigma\gamma + (\sigma\gamma - 1)(2\xi - 1)\right]$$

$$\Theta \equiv \xi \left[\frac{\sigma\gamma-(\sigma\gamma-1)(2\xi-1)}{\sigma\gamma-(\sigma\gamma-1)(2\xi-1)^{\mathbf{2}}}\right]$$

$$\Theta_{i,a} \equiv \gamma \left[\left(\frac{\sigma\gamma-(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(1-\tilde{\eta})}{\sigma-(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(\tilde{\eta}-\tilde{\eta}^*)}\right)\tilde{\lambda}_a + \left(\frac{\sigma(1-\xi)-(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(1-\tilde{\eta})}{\sigma-(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(\tilde{\eta}-\tilde{\eta}^*)}\right)\tilde{\lambda}_a^*\right]$$

$$\Theta_{i,a^*} \equiv \gamma \left[\left(\frac{\sigma\gamma-(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(1-\tilde{\eta})}{\sigma-(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(\tilde{\eta}-\tilde{\eta}^*)}\right)\tilde{\lambda}_{a^*} + \left(\frac{\sigma(1-\xi)-(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(1-\tilde{\eta})}{\sigma-(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(\tilde{\eta}-\tilde{\eta}^*)}\right)\tilde{\lambda}_{a^*}^*\right]$$

$$\begin{aligned}
\tilde{\lambda}_a &\equiv 1 + (\sigma - \frac{1}{\gamma})\left[\frac{\gamma((1-\xi)+(\xi-\xi^*)(1-\tilde{\eta}))}{\varphi(\sigma-(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(\tilde{\eta}-\tilde{\eta}^*))+1}\right] \\
\tilde{\lambda}_{a^*} &\equiv -(\sigma - \frac{1}{\gamma})\left[\frac{\gamma((1-\xi)+(\xi-\xi^*)(1-\tilde{\eta}))}{\varphi(\sigma-(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(\tilde{\eta}-\tilde{\eta}^*))+1}\right] \\
\tilde{\lambda}_a^* &\equiv -(\sigma - \frac{1}{\gamma})\left[\frac{\gamma(\xi^*+(\xi-\xi^*)(1-\tilde{\eta}^*))}{\varphi(\sigma-(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(\tilde{\eta}-\tilde{\eta}^*))+1}\right] \\
\tilde{\lambda}_{a^*}^* &\equiv 1 + (\sigma - \frac{1}{\gamma})\left[\frac{\gamma(\xi^*+(\xi-\xi^*)(\tilde{\eta}^*)}{\varphi(\sigma-(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(\tilde{\eta}-\tilde{\eta}^*))+1}\right]
\end{aligned}$$

$$\begin{aligned}
\tilde{\eta} &\equiv \frac{n\xi}{n\xi+(1-n)\xi^*} \\
\tilde{\eta}^* &\equiv \frac{n(1-\xi)}{n(1-\xi)+(1-n)(1-\xi^*)}
\end{aligned}$$

The model parameters are summarized in Table 2.1 below. Under the benchmark parameterization, the structural parameters of the model are chosen as $\beta = 0.99$, $\gamma = \varphi = 5$, $\sigma = 1.5$, $\xi = 0.06$, and $\alpha = 0.75$, in light of Chari, Kehoe and McGrattan (2002). This is also similar to the closed economy model of Neiss and Nelson (2003) and Neiss and Nelson (2005). We assume that countries are equal in population, $n = 0.5$ and the allocation of home and foreign goods in the consumption basket of each country is symmetric, $\xi = 1 - \xi^*$. We set $\eta = 4$ as described in Gali (2008). We assume that the Taylor rule is inertial and the policy rule is identical in both countries. Following Rudebusch (2006), we set monetary policy parameters estimated to match the U.S. data such that $\rho_i = 0.78$, $\Psi_\pi = 1.24$ and $\Psi_x = 0.33$, and the AR(1) monetary shock process parameters of persistence and volatility such that $\delta_m = 0$ and $\sigma_m = 0.36$, respectively. For the productivity shock process, these parameters are chosen as $\delta_a = 0.97$, and $\sigma_a = 0.73$, as in Heathcote and Perri (2002). Based on their estimates, the cross-country spillover parameter δ_{a,a^*} is set at 0.025.The correlations of domestic and foreign productivity and monetary innovations are $\rho_{a,a^*} = 0.29$ and $\rho_{m,m^*} = 0.5$, following Chari, Kehoe and McGrattan (2002). We assume further that the monetary and productivity innovations are uncorrelated with each other.[8]

[8]Unlike Benati and Surico (2008), where they estimated the model before running their experiments, we have calibrated the model. One possible argument in favor of calibration is that the model is too simplified so we are concerned that estimating it would lead to misspecification bias and, therefore, would complicate the interpretation of our estimates and our subsequent experiments even more.

Structural parameters	
Intertemporal discount factor	$0 < \beta < 1$
Inverse of the intertemporal elasticity of substitution	$\gamma > 0$
Inverse of the Frisch elasticity of labor supply	$\varphi > 0$
Interest semi-elasticity of money demand	$\eta > 0$
Elasticity of substitution across varieties within a country	$\theta > 1$
Elasticity of substitution between Home and Foreign bundles	$\sigma > 0$
Share of Home goods in the Home basket	$0 < \xi < 1$
Share of Home goods in the Foreign basket	$0 < \xi^* < 1$
Home population size, Mass of Home varieties	$0 < n < 1$
Foreign population size, Mass of Foreign varieties	$0 < 1 - n < 1$
Calvo (1983) price stickiness parameter	$0 < \alpha < 1$
Monetary policy parameters	
Monetary policy inertia	$0 < \rho_i < 1$
Sensitivity to deviations from the inflation target	$\Psi_\pi > 1$
Sensitivity to deviations from the potential output target	$\Psi_x > 0$
Shock parameters	
Persistence of the productivity shock	$-1 < \delta_a < 1$
Volatility of the productivity shock	$\sigma_a > 0$
Correl. between Home and Foreign productivity innovations	$-1 < \rho_{a,a^*} < 1$
Persistence of the monetary policy shock	$-1 < \delta_m < 1$
Volatility of the monetary policy shock	$\sigma_m > 0$
Correl. between Home and Foreign monetary innovations	$-1 < \rho_{m,m^*} < 1$

Table 2.1: Model parameters

2.4.2 Simulated forecasts

We run a Monte Carlo simulation of the model with 100 trials and with a subsample of 160 periods for each trial. Using the simulated data, we forecast inflation using one-variable recursive forecasts. We split 160 periods equally between estimation and pseudo out-of-sample forecast samples and conduct forecasts using *i)* domestic and global money growth, *ii)* terms of trade gap and HP-filtered terms of trade, and *iii)* domestic and global output gap. In particular, we calculate the (relative) MSFEs at a grid of points that spans the space for selected parameters, while keeping other parameters at their benchmark values. (We select an interval for the grid search so that the benchmark values of these parameters fall in that interval.) In these 100 trials, we evaluate forecasting performance based on the median (relative) MSFE, median p-value of the hypothesis that the relative MSFE is greater than or equal to 1, and the fraction of statistically significant trials with p-values less than or equal to 10%.

The analyses conducted here can be grouped under three main experiments: *i)* Good luck, *ii)*Monetary policy, and *iii)* Openness.

i) Good luck[9] experiment focuses on how forecasting performance of the regressors listed above is altered when the parameters of innovations, specifi-

[9]In the current terminology, 'good luck' is used in order to explore the possibility of exogenous changes in the distribution of the shock process. These changes might cause a draw of unusually benign shocks to the economy. Good luck might be the result of an unusual draw of shocks from the right-tail of distribution but that is not the interpretation we give here. Rather, we interpret good luck as the shift in the distribution of shocks.

cally the volatility of shocks, σ_m and σ_a take on different values. We run two versions of this experiment. In the first version, we conduct the experiment symmetrically for both countries. Hence for σ_m and σ_a, and σ_{m^*} and σ_{a^*}, we set values both varying within $(0, 2]$. In the second one, we change the parameterization of U.S. only, keeping the ROW parameters constant.

The literature on Great Moderation provides with important empirical findings on the evolution of these variables over time. The Great Moderation era is mainly characterized by reductions in the conditional variance in time-series models. The variance reduction is generally attributed to a smaller error variance, not to changes in the autoregressive coefficients, as suggested by Stock and Watson (2003a), Ahmed, Levin, and Wilson (2002), Blanchard and Simon (2001) and McConnell and Perez-Quiros (2000). Stock and Watson (2003a) calculated a sharp decline in the volatility of the U.S. GDP growth in the first quarter of 1984. Volatility is highest in 1970s, and considerably high in 1960s and early 1980s[10]. They calculate similar volatility declines in macroeconomic variables, including nominal variables such as inflation (GDP deflator) and 90-day T-bill rate. Moreover, Stock and Watson (2005) and Fogli and Perri (2006) document that the moderation is a world-wide phenomenon, also observed in Japan and EU, but the greatest moderation was observed in the U.S. Taking into account this evidence, an asymmetric experiment seems

[10]Stock and Watson (2003a) report the standard deviations of four-quarter growth rate of real GDP. The standard deviation in the post-1984 period is 0.59 times that of the pre-1984 period. (Standard deviation in the 1970-1980 period is highest, but still comparable to its 1960-1970 level.)

more relevant.

Stock and Watson (2003a) provide a helpful comparison of the monetary shock volatilities for the pre-1983 and post-1984 era. Using structural VAR and implementing the methodologies of Christiano, Eichenbaum and Evans (1998) and Bernanke and Mihov (1997),[11] they compute the implied money shocks. Volatility of these monetary shocks exhibited a decline in the great moderation era, following a high level of volatility in 1960-83 and having a peak during 1979-83.[12] Similarly, Smets and Wouters (2007), report a decline in the volatility of both shocks in the US in an extended DSGE model for the Great Moderation era (1984-2004) relative to the Great Inflation era (1966-79).

ii) Our *monetary policy* experiments pay attention to forecasting performance under changes in the monetary policy parameters Ψ_π and Ψ_x, one with high monetary policy inertia, $\rho_i = 0.78$ and one with low inertia, $\rho_i = 0$. For Ψ_π, we try values of grid points in the interval $(1, 3]$ and Ψ_x, in the interval $(0, 2]$. Coibion and Gorodnichenko (2011), among others[13], provide historical estimates of the coefficients of a generalized Taylor rule. Their estimates of Ψ_x do not show much variation from late 1960s to early 2000s. They indicate that both the inertia of the monetary policy and the parameter on inflation

[11] They take into account that the monetary policy shifted over the sample period.

[12] Volatility of money shocks during 1984-2001 is about 0.50 times the volatility in 1960-1983 and about 0.76 times the volatility in 1960-1978 period according to CEE methodology.

[13] See also Stock and Watson (2003) for a summary of historical estimates of Taylor Rule coefficients in the US calculated by Judd and Rudebusch (1998), Taylor (1999) and Clarida, Gali and Gertler (2000).

gap have increased recently. Their time varying estimate for Ψ_π is relatively high in late 1960s as well as early 1980s and onwards, but low during 1970s. A similar pattern is observed for the inertia parameter, ρ_i. The case $\rho_i = 0.78$ in our simulated forecasts is close to the upperbound estimated by Coibion and Gorodnichenko (2011) while $\rho_i = 0$ is not comparable to their lower bound. Rudebusch (2006) provides evidence that for 1990s, a positive inertia parameter in the policy rule is more plausible. However, a non-inertial policy rule is a common benchmark in the literature (e.g. Taylor (1993) and Yellen (2004)) and is therefore a natural case to investigate especially to understand the patterns before 1990s.

iii) The final experiment, *trade openness*, involves a grid search over the parameters of share of Home goods in the Home basket, ξ and elasticity of substitution between Home and Foreign bundles, σ. For ξ we try the values in the intervals $(0, 0.5]$, hence, under the case ξ is close to 0, the economy is almost closed and there is home bias, while under $\xi = 0.5$ there is no bias between consumption and production and the economy is open. For σ, we try values within the range $(0, 2]$ where $\sigma = 1$ implies the consumption aggregator is Cobb-Douglas type.

2.4.3 Results

We illustrate our results from the symmetric *good luck* experiment in Figures B.8-16 in the Appendix. The key results are:

1. If a symmetric change in the volatility of productivity and monetary

shocks in the U.S. and the ROW has a significant effect on the forecasting performance of variables, it is on domestic slack only.

2. Starting from the benchmark parameterization ($\sigma_a = 0.73$ and $\sigma_m = 0.36$) and for a given σ_m (and σ_{m^*}), a decline in σ_a (and σ_{a^*}) might deteriorate the forecasting ability of domestic slack; for a given σ_a (and σ_{a^*}), a decline in σ_m (and σ_{m^*}) might deteriorate the forecasting ability of domestic slack (Figures 5a and 6a). However, it would require a large swing from the benchmark parameterization to see the changes in the forecast accuracy observed in the data.

3. The experiment shows that only in a small fraction of instances (less than 40%) some variables (global slack, domestic money growth and terms of trade gap) seem to be marginally statistically significant.

Hence, in theory, we can conclude that the performance of the traditional Phillips curve based forecasts of U.S. inflation might have changed due to Great Moderation—if it is interpreted as a world-wide phenomenon that affected most countries equally. If we allow for asymmetries à la Fogli and Perri (2006), then HP-filtered terms of trade starts to matter in forecasting U.S. inflation. The results from the asymmetric good luck experiment are depicted in Figures B.16-25:

1. Relative to the symmetric experiment, we observe larger statistically significant regions for domestic slack, global slack, HP-filtered terms of

trade and terms of trade gap and very weak results for domestic and global money supply growth.

2. The volatility changes in productivity and money might make HP-filtered terms of trade a key variable in forecasting inflation.

3. The statistically significant regions for domestic slack and HP filtered terms of trade do not overlap, so if the volatility driving the productivity and monetary shocks change over time, the forecasting performances of these different variables may have been affected in an opposite way: domestic slack's value as a forecasting variable might decline while HP filtered terms of trade gains value and vice-versa.

Since we do not have actual measures of terms of trade gap, in the empirical analysis we use the HP-filtered terms of trade. There are differences between the forecasting power of HP-filtered terms of trade and the terms of trade gap and there is a weak correlation between these two variables for the benchmark parameters (Figure B.53-54).

We show our results from the *monetary policy* experiment with low inertia in Figures B.26-34. The benchmark values for $\Psi_\pi = 1.24$ and $\Psi_x = 0.33$, respectively. We summarize the findings as follows:

1. With low inertia, more aggressive monetary policy on inflation (for a given Ψ_x) increases the percentage of instances in which the forecasting

power is statistically significant. A high anti-inflationary bias of monetary policy can make domestic and global slack stronger in forecasting inflation—while this is also valid for domestic money, global money and terms of trade gap but the effect seems statistically less significant on these variables.

2. For a given Ψ_π, increases in Ψ_x do not seem to have much of an effect on forecast accuracy of variables.

In turn, the pattern is somewhat reversed when we look at the high inertia case (see Figures B.35-43):

1. In this case, the policy does not seem to have a high influence on forecasting ability except for domestic slack—which is also not very strong. For a given Ψ_x increases in the anti-inflation bias of policy (Ψ_π) tend to reduce the share of statistically significant samples. Whenever Ψ_x increases, then the share of statistically significant samples tends to increase for a given Ψ_π.

2. Changes in inertia parameter appear to be key, and perhaps the most influential channel on predictive ability of variables tested in these experiments. When inertia is high, the response of policy is very delayed and using current variables as predictors of inflation can be a bad proxy for what monetary policy does and therefore for how inflation will be in the future.

Our results from the *openness* experiment are shown in Figures B.44-52. The benchmark values for the parameters of interest are $\xi = 0.06$ and $\sigma = 1.5$, respectively.

1. This is the only channel that explains the switches between domestic and foreign variables— however, for the slack variables only. Keeping σ constant, an increase in the share of Home goods in the Home basket, ξ, causes a weaker performance for the domestic output gap, i.e. the traditional closed-economy Phillips curve predicts domestic inflation less accurately while implying a better performance for the open economy Phillips curve.

2. This experiment is silent on why domestic money supply growth may be a good predictor of U.S. inflation while global money supply growth is poor and vice versa.

3. Forecast accuracy is almost invariant to changes in the elasticity of substitution between Home and Foreign bundles, σ (for a given ξ) especially in the neighborhood of the benchmark parameterization.

We provide a summary of results in Table 2.2 where we show which channels in the model might play a statistically significant effect in forecasts in at least 50% of the time. We draw three important conclusions from these experiments (if we consider movements relative to the benchmark parameterization):

- Phillips curve based forecasts of inflation may be affected by a combination of all three channels: good luck, monetary policy and openness.

- Asymmetric changes in volatilities of productivity and monetary shocks can be responsible for the high performance of HP-filtered terms of trade.

- There is nothing that matters more than monetary policy in the performances of all variables tested here except for HP-filtered terms of trade. And it is clear that it is the systematic part that is the key determinant of when and how these variables become more useful for forecasting. It is not only the response to inflation that matters a lot (the response to the output gap has only minor effects in our current experiments), but the fact that policy responses could be gradual or abrupt.

Having established the main findings from the simulated forecasts, we move to the next section where we aim to explain how primary domestic and global macroeconomic phenomena since 1960s affected the predictive accuracy of our variables and what accounts for these changes.

2.4.4 Relating theory to stylized facts

Now we turn to Figures B.2-7 in order to explain how major episodes for the U.S. economy can be related to forecasting performances. We analyze these figures paying particular attention to CPI inflation, since the model at

		Domestic slack	Global slack	ToT HP-filtered	ToT gap	Domestic money	Global money
Good luck	σ_m	✓					
(symmetric)	σ_a	✓					
Good luck	σ_m	✓	✓	✓	✓		
(asymmetric)	σ_a	✓	✓	✓	✓		
Monetary policy	Ψ_π	✓	✓		✓	✓	✓
(low inertia)	Ψ_x						
Monetary policy	Ψ_π	✓					
(high inertia)	Ψ_x	✓					
Openness	ξ	✓	✓				
	σ						

Table 2.2: Predictive performances of variables

Note: This table reports whether changes in a given parameter have a statistically significant impact on predictive ability of a variable (at least at 10% significance level) in at least 50% of the trials of the experiment.

hand is consistent with this measure of inflation. However, forecasting patterns are robust to other measures of inflation to a great extent.

- *Domestic (US) and global (G7) money supply growth:* Figures B.2-3 reveal that especially at long horizons, US money supply growth helps forecast US inflation starting in late 1960s until mid 1970s. In samples starting earlier or later than this period, we obtain lower forecast accuracy for this variable relative to naive forecasts. Interestingly, the periods that US money supply growth does not perform well in general coincide with the periods G7 money supply growth performs well. Our model suggests that these variables can matter for forecasting only because of monetary policy and especially when monetary policy is non-inertial ($\rho_i = 0$), and highly anti-inflationary (i.e. high Ψ_π). On the other hand, the historical estimates for the monetary policy parameters during the 1970s reveal that inertia was low but the monetary policy was not anti-inflationary. Hence, none of these variables should have high performance during the 1970s as well as outside the 1970s. Therefore, periods during which any of these variables perform well are puzzling in light of our model and we only explain why they do not perform well.

- *Domestic (CBO) and global (OECD) slack:* Figures B.4-5 show that forecasts with domestic slack (i.e. the traditional closed-economy Phillips curve-based forecasts) perform well until 1960s, but any forecast that is based on a sample starting after 1960s in general is less accurate than a naive forecast. According to our model, one channel that can explain this is openness. The model suggests that under low trade openness, we should expect a high predictive performance by U.S. slack. In addition, a combination of high monetary policy shock volatility (σ_m) and high productivity shock volatility (σ_a) might have improved this performance while the stance of monetary policy (high anti-inflation bias of policy (Ψ_π) with high monetary policy inertia (ρ_i)) could have reduced it. Overall, the net effect of these channels might have resulted in a high forecast accuracy in the 1960s.

In the 1970s, both the anti-inflation bias and inertia of monetary policy were low, so this would cause a low performance both domestic and global slack according to our theory especially at long horizons which should be the leading explanation for the low performance of Phillips curve-based forecasts. The volatility of shocks, σ_a and σ_m, remained high in this period which could revert the low performance of slack measures, but monetary policy appears to be a stronger channel that dominates any positive effect in this period. Increasing openness should be another reason for lower forecast accuracy of domestic slack.

In the 1980s where openness is highest, the open economy Phillips curve-based forecast starts to outperform both the traditional Phillips curve and the naive forecast. Global slack starts to perform well occasionally in late 1980s and at short horizons, which can be explained only by higher openness.

Highly persistent and highly anti-inflationary policy during the Volcker era (starting 1979) can be shown to weaken the accuracy of both domestic and global slack in this era. The deterioration in forecast accuracy becomes more serious when we also take into account the great moderation era starting in mid-1980s, where the volatility of shocks decline. Our results are in line with Benati and Surico (2008), who suggest, based on a time-varying VAR, that inflation's predictability fell as the persistence of inflation and as the Taylor rule coefficient on the inflation gap rose during the Volcker era. We confirm these results under *high inertia* particularly in forecasts with domestic and global slack measures.

- *Terms of trade gap (HP-filtered terms of trade and terms of trade ex. oil):* While in the empirical analysis we use HP-filtered terms of trade and HP-filtered terms of trade ex. oil as proxies for the terms of trade gap, in the NOEM framework we do not separate between these two variables and therefore we only focus on HP-filtered terms of trade in this section. HP-filtered terms of trade kicked in as a good forecast variable starting in late 50s and the performance went well until present except for a break with the estimation samples starting in the early 1980s. The monetary policy and openness experiments do not help us understand the performance of this variable, while the good luck (asymmetric) experiment stands out as the only relevant and important case that can explain the patterns in Figures B.6-7. A sufficiently high combination of the volatility shocks, σ_a and σ_m, during 1960 and 1970s might have caused a high performance by HP-filtered terms of trade (and in theory, terms of trade gap). In the late 1970s, the volatility of shocks peaked, which might have caused the variable to move to the insignificant region in Figure 8b. During the Great Moderation era, the decline in the volatility of shocks might be responsible for a weak performance.

Going back to the first question raised in the previous section, we now have a more clear understanding on what determines the accuracy of forecasts with domestic and global slack measures. While globalization seems to be the only channel to make global slack a better forecasting variable than domestic slack, the conduct of monetary policy and particularly the monetary policy inertia matter most in forecasting U.S. inflation can become a significant determinant of forecast accuracy of all other variables tested here.

We also understand to a great extent why terms of trade can be a good forecasting variable—it is basically due to good luck. Our simulated forecasts obviously cannot explain the occasionally good performance of terms of trade ex. oil and we leave this as an open question to be investigated in the future.

We also document an interesting puzzle regarding the forecasts with domestic and global money supply growth, an alternating pattern in the relative MSFEs of the two variables especially until mid-1980s. This is one case the current model cannot explain. We believe that a plausible explanation is that the strong connection between the US and global money supply during the Bretton Woods era might have weakened by the collapse of the system in

1971 (therefore its relationship between US inflation also weakened) causing the weak performance of G7 money supply growth during 1970s which was a useful forecasting variable before the 1970s. Also, in a recent study, Sargent and Surico (2011) provide results on the empirical evidence of the quantity theory of money that may explain the performance of US money growth in forecasting US inflation. Our empirical findings are consistent with their estimates for 1970s where the quantity theory of money seemed to exist but then broke down starting in late 1970s. We believe that the current model does not help us see this connection exactly since the NOEM model does not capture a strong role for money supply. However, this should not be viewed as a serious issue since both domestic and global money growth seem to have lost their significances in forecasting U.S. inflation during the post-1984 period.

Finally, we still leave an open question on why the HP-filtered slack measures perform as good as the slack measures that are calculated with a production function approach. While we believe that this question must be handled with a more formal analysis (which will be left as future work) we provide some interesting findings in Figures B.53-57. Lack of structural estimates of output gap might be by-passed by using HP-filtered output in certain cases; however we show that it may not always be a good proxy for output gap. Changes in the structural parameters of the models may significantly affect the correlations between output gap and its HP-filtered counterpart.

2.5 Conclusion

Beating the naive forecasts of U.S. inflation with a traditional Phillips curve specification has become difficult over the past three decades. The major contribution of our paper is to help solve this problem, introducing a variable, HP-filtered terms of trade, to forecast U.S. inflation. We documented that it yields highly accurate forecasts relative to the naive forecasts of U.S. inflation. It also does well compared to forecasts with several conventional measures: domestic slack, global slack, domestic money supply growth and global money supply growth.

Our second contribution is to bring together and compare three channels regarding forecast accuracy that are widely discussed in the literature -globalization, monetary policy and good luck- under a single NOEM framework to explain our empirical findings. We provide three key insights: (i) monetary policy inertia is an important parameter in raising the significance of a given variable to forecast U.S. inflation, and the conduct of monetary policy appears to be the most important channel, (ii) volatilities of shocks to productivity and money can be a particularly important determinant of the accuracy of forecasts with HP-filtered terms of trade (iii) and a combination of these three channels might have improved the performance of HP-filtered terms of trade while deteriorating that of the Phillips curve-based forecasts during the Great Moderation era.

Appendices

Appendix A

Appendix to chapter 1

A.1 List of countries

The following countries constitute the rest of the world:

1. Japan

2. Euro Area: Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, the Netherlands, Portugal, Slovakia, Slovenia, and Spain.

3. Oil Exporters: Algeria, Angola, Azerbaijan, Bahrain, Republic of Congo, Ecuador, Equatorial Guinea, Gabon, I.R. of Iran, Kuwait, Libya, Nigeria, Norway, Oman, Qatar, Russia, Saudi Arabia, Syrian Arab Republic, Turkmenistan, United Arab Emirates, Venezuela, and the Republic of Yemen.

4. Emerging Asia: China, Hong Kong SAR, Indonesia, Korea, Malaysia, the Phillipines, Singapore, Taiwan Province of China, and Thailand.

A.2 Computational Algorithm

A.2.1 Pre-reform steady state:

I provide the algorithm for the case with inelastic labor supply.

1. Create grids on next period's assets and this period's shocks, (a', ε). Define $a' \epsilon A = \{a_1, a_2, ..., a_N\}$ where a_1 is the borrowing limit in each country; and define the productivity shocks so that. $\varepsilon \; \epsilon E = \{\varepsilon_{1,...}, \varepsilon_M\}$.

2. Make a guess on the world interest rate, r. Notice that $r \in (0, 1/\beta - 1)$. Set values for D_0 and D_0^*. Given the tax rates, it is straightforward to compute the implied K/N ratio and remaining factor prices for both countries: r^k, r^{k*} , w and w^*.

3. Make a guess for the initial cumulative distribution of households over assets and shocks, $\Gamma_0(a', \varepsilon)$. A uniform distribution function is a good guess.

4. Make an initial guess on tomorrow's consumption policy function, $c_0(a', \varepsilon)$. A good guess can be based on the budget constraint.

5. Construct the RHS of the Euler equation, for all pairs of $(a', \varepsilon) \; \epsilon \; A \times E$

$$RHS = \beta(1+r) \sum_{\varepsilon' \epsilon E} \Pi(\varepsilon'|\varepsilon) U_c(c_0(a', \varepsilon))$$

6. Using the Euler equation, solve for today's consumption function algebraically. I.e. find $\tilde{c}$ that solves

$$U_c(\tilde{c}) = RHS$$

Note that this step makes the computation very efficient and fast compared to methods that require a nonlinear equation solver.

7. Using the budget constraint, compute today's asset holdings $\bar{a}(a', \varepsilon)$ such that

$$\bar{a}(a', \varepsilon) = [\tilde{c} + a' - Nw(1 - \tau^n)\varepsilon]/(1 + r) \tag{A.1}$$

Hence, we find today's assets given tomorrow's asset holding is a' and today's productivity shock is ε. Notice that $\bar{a}(a', \varepsilon)$ is not necessarily on the grids defined in A, that is, the grids we find now are endogenous grid points. Update the initial guess for consumption as follows.

a. If $\bar{a}(a', \varepsilon)$ causes the borrowing constraint to bind next period, compute the new guess $\tilde{c}_0(a', \varepsilon)$ using piecewise linear interpolation on the closest grid points a_i and a_j such that, $a_i < \bar{a}(a', \varepsilon) < a_j$ and using consumption rules at $c_0(a_i, \varepsilon)$ and $c_0(a_j, \varepsilon)$.

b. If $\bar{a}(a', \varepsilon)$ causes the borrowing constraint not to bind next period, then set $\tilde{c}_0(a', \varepsilon) = \tilde{c}$ from step 6.

8. Check convergence for any asset grid and productivity shock, based on the metric

$$\max\{|\tilde{c}_0(a',\varepsilon) - c_0(a',\varepsilon)|\} < \varepsilon$$

where ε is a small number. If convergence is not achieved, go to step 5.

9. Given the initial guess for distribution, $\Gamma_0(a',\varepsilon)$, interpolate on grid points a_i and a_j to find the distribution over the endogenous grid points, $\Gamma(h_a^{-1}(a',\varepsilon)),\varepsilon)$. The inverse of the policy functions is already calculated in an earlier step, which makes this step also very efficient. Hence $h_a^{-1}(a_{t+1},\varepsilon_t) = \bar{a}(a',\varepsilon)$. Then using the Markov transition matrix, find tomorrow's distribution

$$\Gamma(a',\varepsilon') = \sum_{\varepsilon} \Pi(\varepsilon'|\varepsilon)\Gamma(\bar{a}(a',\varepsilon),\varepsilon)$$

Construct a metric as in step 8 to check convergence.

10. Repeat these steps for two countries, compute aggregate savings and check whether global asset market clears. Update the interest rate, r using bisection method.

11. Calculate the output level, and check if the public debt-to-GDP ratio is satisfied. Then calculate the implied government expenditure, G.

A.2.2 Transition and post-reform steady state:

1. Set T, the number of periods to converge to the new steady state.

2. Pick a new value for τ^k. The new tax is imposed before the decisions are made in period 1.

3. Make a guess for the path of Home capital stock, $\{K_t\}_{t=2}^{T-1}$. Given that the labor supply is inelastic, the implied series for factor prices and $\{K_t^*\}_{t=2}^{T-1}$ can be obtained.

4. Using the government budget constraint for all periods, and for given values of D_0 and G, find the new implied labor income tax, τ^n. It is convenient to assume that $D_T = D_{T-1}$ as in Domeij and Heathcote (2004).[1]

5. Having found τ^n, find the sequence of government debt, $\{D_t\}_{t=2}^{T}$. Repeat this for Foreign.

6. Calculate the post-reform steady state, following the instructions in the pre-reform steady state.

7. For both countries, solve for the household's optimization problem along the transition path, starting from the final steady state going backwards.

[1] A full shooting algorithm is explained in Mendoza and Tesar (1998). Their methodology would require me to make a guess on the new τ^n, check whether the present value of the government budget is satisfied and update τ^n if necessary. Given the complexity of heterogeneous-agent incomplete markets models, the current technique is more conveniently applied.

Application of the endogenous grid point method is similar to the description in the pre-reform steady state above. Find the consumption rules back until period 1. Find the implied asset holdings, and the post-tax household distribution over assets and productivity shocks at period 1.

8. Then update the distributions forward, using the Markov transition matrix and households' optimal saving decisions. Do the aggregations, compute the implied sequence of capital stock $\{\tilde{K}_t\}_{t=2}^{T-1}$ for Home using $\tilde{K}_t = A_t - D_t + A_t^* - K_t^* - D_t^*$.

9. Check whether the inital path of capital stock has converged to the implied series. If so, check whether T is sufficiently large or not.

Appendix B

Appendix to chapter 2

B.1 Data Description

Abbreviations

BEA = U.S. Bureau of Economic Analysis; BLS = U.S. Bureau of Labor Statistics; BBK =German Federal Bank; BIS = Bank for International Settlements; CAO = Cabinet Office (Japan); CBO = Congressional Budget Office; FRB = Federal Reserve Board; FRBD = Federal Reserve Bank of Dallas; FRED = Federal Reserve Economic Data (St. Louis Fed); IMF = International Monetary Fund; INSEE = National Institute of Statistics and Economic Studies (France); ISTAT = Istituto Nazionale Di Statistica (Italy); OECD= Organisation for Economic Cooperation and Development; OECD-MEI= OECD Main Economic Indicators; ONS = Office for National Statistics (UK); SAAR = Seasonally adjusted at an annual rate; SA=Seasonally adjusted; SCAN = Statistics Canada

All series are quarterly unless indicated otherwise and obtained from Haver Analytics. In general, we indicate the original source if the series is available outside Haver Analytics. While we try to be consistent in terms of the definitions across countries, under cases in which data availability is limited, we use the series with the closest definition.

1. **Price indices**

Series used for U.S. inflation: All series are seasonally adjusted. Start dates of the series vary across different measures and they all end in 2011:4.

Base years and start dates of each series are indicated in parentheses. We take CPI (all items) (82-82=100, 1947:1) from the BLS, core CPI (all items ex. food and energy) (82-84=100, 1957:1) from the BLS, GDP implicit price deflator (82-84=100, 1947:1) from the BEA; PCE chain price index (2005=100, 1959:1) from the BEA, trimmed mean PCE chain price index (2004-5=100, 1977:1) from FRBD and PPI (finished goods) (1982=100, 1947:2) from the BLS. Series used for terms of trade gaps: We use exports and imports under the heading 'price indexes for GDP' in National Income and Product Accounts in BEA to calculate U.S. terms of trade. Both series are seasonally adjusted, with the base year 2005=100 and cover periods 1947:1-2011:4. Terms of trade series is calculated as 100 $\times$export price index/import price index. Terms of trade gap is the HP-filtered ($\lambda = 1600$) terms of trade series. Terms of trade gap ex. oil is calculated similarly (with the same base year and seasonally adjusted), using imports of non-petroleum goods (chain price index) and exports of goods (chain price index) from BEA (1967:2-2011:4).

2. **Monetary aggregates**

All series are seasonally adjusted and quarterly (end-of-period aggregates of monthly series). For UK and U.S., we have M4 and M2 data available from OECD and FRB (1963:1-2011:4), respectively. For other countries, data become limited for certain periods and sources and therefore we splice two series. Therefore we obtain M3 for Canada from BIS (1962:1-1981:4) and OECD (1982:1- 2011:4); M2 for Germany from BIS (1963:1-1990:4) and BBK (1980:1-2011:4); M2 for Italy from Bank of Italy (1963:1-1997:1/1997:2-2011:4); M2 for Japan from Bank of Japan (1963:1-1966:4) and FRED (1967:1-2011:4). For France, we splice M2R and M3 from BIS (1963:1-1969:4 and 1970:1-2011:4, respectively). For France, Germany and Italy, the first part of the series is converted from the national currency to Euros using the European Currency Unit (1999).

3. **Slack measures**

All measures used cover the period 1980:1-2011:4 unless stated otherwise.

CBO U.S. slack: Defined as 'Output Gap in Percentage of Real GDP', and is calculated as

$$\frac{100 \times \ (RPGDP_t - RGDP_t)}{RGDP_t}$$

where $RPGDP_t$ and $RGDP_t$ are real potential GDP and real GDP at quarter t, respectively (SAAR, Billions of Chained 2005 Dollars). We take our real GDP series from BEA and real potential GDP series from CBO. U.S. HP-filtered series is simply quarterly U.S. real GDP series with HP filter ($\lambda = 1600$) applied. Then the logs of the cyclical component is taken and multiplied by 100.

FRBD U.S. slack: The series is constructed by the FRBD, and the methodology can be described as follows. First, the Phillips Curve is estimated with annualized quarterly inflation (specifically, core CPI) and unemployment rate/capacity utilization rate. The regression equation for this is specified as is constructed as follows.

The regression is specified as

$$\pi_t = \alpha_1 + \alpha_2\pi_{t-1} + \alpha_3\pi_{t-2} + \alpha_4\pi_{t-3} + (1 - \alpha_2 - \alpha_3 - \alpha_4)\pi_{t-4} + \alpha_5 ur_t + \epsilon_t$$

where $\pi_t = 400 \times \log(p_t/p_{t-1})$, p_t is the price index, ur_t is unemployment rate where we define the potential unemployment rate as $ur^* = -\hat{\alpha}_1/\hat{\alpha}_5$. We run a similar regression with capacity utilization rate, $capu_t$ and define the potential rate of capacity utilization, $capu^* = -\hat{\alpha}_1/\hat{\alpha}_5$, similarly.

Then the slack measure is computed as follows by running the following regression

$$\pi_{t+4} - \pi_t = -\beta_1(ur_t - ur^*) + (1-\beta_1)(capu_t - capu^*) + \epsilon_t$$

and the slack measure is calculated as $slack_t = -\hat{\beta}_1(ur_t - ur^*) + (1 - \hat{\beta}_1)(capu_t - capu^*)$.

FRBD G7 slack: Produced by the FRBD and calculated by applying the procedure described above for each member of the G7 economies. After obtaining the 'domestic slack measure for a given country, the GDP shares of each country is calculated so that for country i at quarter t, $share_{i,t}$=$GDP_{i,t}$ / $\sum_i GDP_{i,t}$. The G7 slack is the GDP-weighted average of the slack measures of individual countries.

The data series we use here are as follows:

- GDP series to construct the GDP shares of each country (sources indicated in parentheses): Canada (SCAN), France (INSEE), Germany (BBK), Italy (ISTAT), Japan (CAO), UK (ONS), U.S. (BEA).

All series are in billions of U.S. Dollars, seasonally adjusted (1978:1-2011:4). For France, Germany and Italy, the series are working day adjusted.

- Manufacturing capacity utilization rates (%) come from manufacturing surveys, covering the period 1978:1-2011:4 and are seasonally adjusted for the following countries: France, Germany and U.S. For Italy, the data come from OECDMEI; for Japan, we use manufacturing operation rate; for Canada, we do splicing for capacity utilization rate from OECDMEI (1978:1-1986:4) and the manufacturing survey from SCAN (1987:1-2011:4); while we apply a similar procedure for UK with capacity utilization rate series from Datastream (1978:1-1985:1) and the manufacturing survey from OECDMEI (1985:2-2011:4).

- As a measure of inflation, we use core CPI. All series are seasonally adjusted, come from OECDMEI and the base year is 2005=100 for all countries with the exception that the base year is 2010=100 for Japan and 82-84=100 for the U.S..

FRBD G39 Slack: This measure is calculated by HP filtering ($\lambda = 1600$) of FRBD G39 index which uses constant 2005 (PPP adjusted) weights to aggregate GDP series of the 39 countries: Argentina, Australia, Austria, Belgium, Brazil, Canada, China, Czech Republic, Denmark, Finland, France, Germany, Greece, Hong Kong, Hungary, India, Indonesia, Italy, Ireland, Japan, Korea, Luxembourg, Malaysia, Mexico, Netherlands, New Zealand, Norway, Peru, Poland, Singapore, South Africa, Spain, Sweden, Switzerland, Taiwan, Thailand, Turkey, UK and U.S. GDP series used are quarterly; and for some countries for which only disaggregated (annual) data are available, we apply quadratic match average method to interpolate these series. We use 2005 PPP data from the IMF.

IMF U.S. and IMF Advanced Slack: Both slack measures are defined as 'Output Gap in Percentage of Real GDP (%)' for the U.S. and for a group of advanced countries (Australia, Austria, Belgium, Canada, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, UK and U.S.). These measures are published by IMF WEO, annually and available between 1980-2011. Therefore we interpolate the series by 'quadratic match average' method to disaggregate into quarterly frequency.

OECD U.S., OECD G7 and OECD Total Slack: All three measures are defined as the 'Output Gap of the Total Economy (%)', published by OECD Economic Outlook. OECD Total consists of 30 OECD countries: Australia, Austria, Belgium, Canada, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland, Turkey, UK and U.S. and the series go back to 1970:4.

U.S. HP-filtered GDP: Calculated using quarterly U.S. real GDP series from BEA. First, the logs of the series is taken and multiplied by 100 and then Hodrick-Prescott filter ($\lambda = 1600$) is applied.

B.2 Tables and Figures

	Relative MSFEs– 1992Q1:2011Q4											
Horizon	**1**	**4**	**6**	**8**	**10**	**12**	**1**	**4**	**6**	**8**	**10**	**12**
	Consumer Price Index						**Consumer Price Index (ex. Food & Energy)**					
AR	4.704	1.881	1.334	1.164	1.065	0.958	0.295	0.418	0.626	0.828	0.954	1.036
CBO	0.990*	1.042	1.059	1.070	1.100	1.168	1.135	0.974*	0.873**	0.827**	0.840**	0.870*
FRBD	0.878***	0.936*	0.924*	0.936*	1.001	1.073	1.333*	0.955**	0.788**	0.737**	0.733**	0.751**
IMF	1.005	1.054	1.068	1.072	1.101	1.170	1.060	1.110	1.106	1.082	1.073	1.079
OECD	0.984*	1.028	1.038	1.046	1.068	1.118	1.018	0.801***	0.741***	0.739**	0.768**	0.798**
HP-filt.	0.997	1.045	1.036	1.022	1.032	1.069	1.103	0.916**	0.851**	0.838**	0.861**	0.882*
Money	0.996	1.017	1.030	1.075	1.100	1.147	1.027	0.969	0.893	0.898	0.920	0.923
	PCE Price Index						**Trimmed Mean PCE Price Index**					
AR	2.329	1.190	0.930	0.885	0.875	0.899	0.142	0.169	0.229	0.313	0.386	0.436
CBO	0.999	1.026	1.041	1.051	1.069	1.082	0.960**	0.882**	0.869**	0.887*	0.904*	0.922*
FRBD	1.006	1.032	1.037	1.030	1.024	1.023	0.933***	0.888**	0.826**	0.822**	0.822**	0.808**
IMF	1.005	1.024	1.032	1.038	1.055	1.067	1.018	1.047	1.029	1.018	1.004	0.986
OECD	0.995	1.012	1.020	1.027	1.040	1.048	0.899***	0.798***	0.820**	0.860**	0.890*	0.918
HP-filt.	1.004	1.020	1.018	1.024	1.038	1.045	0.932***	0.904**	0.922*	0.939*	0.954	0.959
Money	1.002	1.020	1.045	1.078	1.091	1.125	1.017	1.070	1.084	1.109	1.123	1.131
	GDP Deflator						**Producer Price Index**					
AR	0.508	0.376	0.423	0.498	0.545	0.575	19.431	7.829	4.724	3.127	2.207	1.786
CBO	1.005	0.996	1.030	1.040	1.055	1.066	0.980*	1.007	1.032	1.039	1.073	1.119
FRBD	0.949**	0.910**	0.962*	0.997	1.036	1.050	1.005	1.064	1.102	1.137	1.188	1.250
IMF	1.037	1.057	1.059	1.048	1.057	1.065	0.996	1.024	1.053	1.082	1.143	1.227
OECD	0.970**	0.951*	0.999	1.022	1.037	1.047	0.974**	0.989	1.001	0.999	1.006	1.013
HP-filt.	1.013	1.032	1.042	1.031	1.046	1.056	0.909***	0.980*	1.016	1.030	1.073	1.116
Money	1.004	1.033	1.057	1.074	1.090	1.108	1.000	1.011	1.035	1.068	1.101	1.157

Table B.1: Benchmark sample forecasts with US slack and money growth

This table reports the forecasting performances with an estimation sample covering 1980Q1:1991Q4 and a pseudo out-of-sample forecasting sample over 1992Q1:2011Q4. The first row of each panel shows the MSFEs of forecasts with the simple univariate AR process of inflation (restricted model) and are therefore in absolute terms. The second entry in each panel reports the relative MSFEs of the univariate forecasts with terms of trade. The remaining entries are the MSFEs of the bivariate forecasts relative to the MSFEs of the restricted model. Asterisks denote that the relative MSFEs are statistically different and (more accurate) than the MSFEs of the restricted model at 1 (***), 5 (**), and 10 (*) percent significance levels.

							Relative MSFEs– 1992Q1:2011Q4					
Horizon	**1**	**4**	**6**	**8**	**10**	**12**	**1**	**4**	**6**	**8**	**10**	**12**
	Consumer Price Index						**Consumer Price Index (ex. Food & Energy)**					
AR	4.704	1.881	1.334	1.164	1.065	0.958	0.295	0.418	0.626	0.828	0.954	1.036
FRBDG7	0.977*	1.049	1.014	1.017	1.049	1.076	0.947**	0.912**	0.776**	0.740**	0.745**	0.769**
FRBDG39	1.008	1.080	1.076	1.067	1.081	1.135	1.165	0.905**	0.872**	0.871**	0.889*	0.906*
IMFAdv.	1.005	1.050	1.054	1.046	1.041	1.059	1.018	1.054	1.058	1.039	1.023	1.014
OECDG7	0.981	1.036	1.049	1.060	1.067	1.087	0.905***	0.769***	0.680***	0.668***	0.699**	0.735**
OECD Tot.	0.989*	1.045	1.061	1.073	1.081	1.101	0.968**	0.816***	0.701***	0.677***	0.703**	0.738**
G7 Money	1.020	0.962*	0.919**	0.892**	0.835**	0.779***	1.027	0.969*	0.893**	0.898**	0.920*	0.923*
	PCE Price Index						**Trimmed Mean PCE Price Index**					
AR	2.329	1.190	0.930	0.885	0.875	0.899	0.142	0.169	0.229	0.313	0.386	0.436
FRBDG7	0.934***	1.059	1.045	1.083	1.130	1.131	1.001	0.895**	0.830**	0.845**	0.869*	0.891*
FRBDG39	1.009	1.029	1.026	1.039	1.063	1.079	0.994*	0.875**	0.847**	0.879**	0.885*	0.891*
IMFAdv.	1.006	1.013	0.993	0.977	0.966	0.960	0.975**	0.707***	0.659***	0.677***	0.707**	0.757**
OECDG7	0.994	1.018	1.018	1.017	1.016	1.014	0.870	0.686	0.701	0.764	0.823	0.878
OECD Tot.	0.999	1.024	1.023	1.022	1.022	1.021	0.914	0.704	0.696	0.764	0.836	0.898
G7 Money	1.028	0.903**	0.915**	0.889**	0.820***	0.796***	0.982*	1.004	1.054	1.068	1.059	1.066
	GDP Deflator						**Producer Price Index**					
AR	0.508	0.376	0.423	0.498	0.545	0.575	19.431	7.829	4.724	3.127	2.207	1.786
FRBDG7	1.053	0.989	0.991	1.013	1.059	1.074	1.009	1.050	1.052	1.061	1.050	1.023
FRBDG39	1.056	1.078	1.067	1.044	1.072	1.094	0.947**	1.046	1.074	1.154	1.313	1.389
IMFAdv	0.996	0.780***	0.811**	0.887*	0.951	1.000	0.990*	1.020	1.051	1.078	1.106	1.134
OECDG7	0.992	1.001	1.026	1.026	1.029	1.029	0.964**	0.994	1.018	1.031	1.039	1.034
OECD Tot.	1.005	1.015	1.035	1.032	1.037	1.038	0.971**	1.003	1.027	1.040	1.047	1.041
G7 Money	1.009	1.012	1.006	0.988	0.950	0.927	1.023	1.009	1.005	1.018	1.056	1.048

Table B.2: Benchmark sample forecasts with global slack and money growth

This table reports the forecasting performances with an estimation sample covering 1980Q1:1991Q4 and a pseudo out-of-sample forecasting sample over 1992Q1:2011Q4. The first row of each panel shows the MSFEs of forecasts with the simple univariate AR process of inflation (restricted model) and are therefore in absolute terms. The second entry in each panel reports the relative MSFEs of the univariate forecasts with terms of trade. The remaining entries are the MSFEs of the bivariate forecasts relative to the MSFEs of the restricted model. Asterisks denote that the relative MSFEs are statistically different and (more accurate) than the MSFEs of the restricted model at 1 (***), 5 (**), and 10 (*) percent significance levels.

	Relative MSFEs– 1992Q1:2011Q4											
Horizon	**1**	**4**	**6**	**8**	**10**	**12**	**1**	**4**	**6**	**8**	**10**	**12**
	Consumer Price Index						**Consumer Price Index (ex. Food & Energy)**					
AR	4.704	1.881	1.334	1.164	1.065	0.958	0.295	0.418	0.626	0.828	0.954	1.036
ToT	0.963**	0.937**	1.055	1.132	1.247	1.312	1.120	1.221	1.173	1.086	1.057	1.061
CBO&ToT	0.981*	1.016	1.227	1.339	1.508	1.623	1.179	1.133	1.030*	0.929**	0.921*	0.958*
FRBD&ToT	0.903***	0.987*	1.177	1.283	1.461	1.568	1.302	1.015	0.872	0.810*	0.802*	0.829
IMF&ToT	0.995**	1.011*	1.215	1.332	1.504	1.612	1.030	1.009	0.922*	0.879**	0.873*	0.885*
OECD&ToT	0.973**	0.986*	1.187	1.295	1.456	1.557	1.079	0.974*	0.904*	0.843**	0.851*	0.890*
HP-filt.&ToT	0.992**	1.034	1.216	1.292	1.453	1.558	1.225	1.137	1.021	0.926*	0.926*	0.955
US Money&ToT	0.953**	0.974*	1.098	1.215	1.351	1.448	1.116	1.327	1.305	1.228	1.218	1.248
G7 Money&ToT	1.014	1.005	1.096	1.169	1.221	1.206	1.127	1.161	1.050	0.984	0.987	1.007
	PCE Price Index						**Trimmed Mean PCE Price Index**					
AR	2.329	1.190	0.930	0.885	0.875	0.899	0.142	0.169	0.229	0.313	0.386	0.436
ToT	0.916***	0.892**	0.974	1.116	1.252	1.283	0.963	0.911**	0.864**	0.828***	0.833**	0.843**
CBO&ToT	0.899	0.883	0.980	1.126	1.274	1.318	1.053	0.873**	0.777***	0.790**	0.784**	0.783**
FRBD&ToT	0.907	0.898	0.989	1.139	1.276	1.305	0.950**	0.899**	0.828**	0.803**	0.834**	0.867*
IMF&ToT	0.912***	0.882**	0.976*	1.128	1.278	1.319	1.029	0.967*	0.877**	0.843**	0.848**	0.863*
OECD&ToT	0.896***	0.873**	0.965*	1.108	1.251	1.293	0.992**	0.809***	0.742***	0.768**	0.768**	0.774*
HP-filt.&ToT	0.916***	0.917**	1.004	1.153	1.302	1.341	1.001*	0.892**	0.802**	0.804**	0.788**	0.765**
US Money&ToT	0.909***	0.956*	1.089	1.303	1.459	1.479	1.039	0.972	0.890	0.914	0.902	0.854
G7 Money&ToT	0.980**	0.876**	0.986	1.088	1.144	1.157	1.044	0.946*	0.898**	0.907*	0.886*	0.853**
	GDP Deflator						**Producer Price Index**					
AR	0.508	0.376	0.423	0.498	0.545	0.575	19.431	7.829	4.724	3.127	2.207	1.786
ToT	1.072	1.155	1.129	1.105	1.158	1.200	0.968**	0.967*	1.034	1.141	1.315	1.377
CBO&ToT	1.028	1.027	1.108	1.133	1.199	1.261	0.965**	0.997	1.085	1.207	1.431	1.550
FRBD&ToT	0.982	1.089	1.139	1.141	1.206	1.255	0.980**	1.040	1.145	1.304	1.550	1.676
IMF&ToT	1.088	1.163	1.150	1.125	1.178	1.226	0.971**	0.999	1.101	1.259	1.530	1.687
OECD&ToT	0.988	0.993	1.086	1.123	1.189	1.247	0.961**	0.969*	1.039	1.146	1.335	1.409
HP-filt.&ToT	1.053	1.110	1.158	1.154	1.212	1.260	0.970**	1.011	1.091	1.226	1.467	1.602
US Money&ToT	1.081	1.252	1.231	1.224	1.269	1.306	0.961**	0.971*	1.078	1.248	1.479	1.582
G7 Money&ToT	1.077	1.190	1.171	1.124	1.142	1.171	1.008	1.003	1.059	1.178	1.372	1.411

Table B.3: Benchmark sample forecasts with domestic variables and terms of trade

This table reports the forecasting performances with an estimation sample covering 1980Q1:1991Q4 and a pseudo out-of-sample forecasting sample over 1992Q1:2011Q4. The first row of each panel shows the MSFEs of forecasts with the simple univariate AR process of inflation (restricted model) and are therefore in absolute terms. The second entry in each panel reports the relative MSFEs of the univariate forecasts with terms of trade. The remaining entries are the MSFEs of the bivariate forecasts relative to the MSFEs of the restricted model. Asterisks denote that the relative MSFEs are statistically different and (more accurate) than the MSFEs of the restricted model at 1 (***), 5 (**), and 10 (*) percent significance levels.

	Relative MSFEs– 1992Q1:2011Q4											
Horizon	**1**	**4**	**6**	**8**	**10**	**12**	**1**	**4**	**6**	**8**	**10**	**12**
	Consumer Price Index						**Consumer Price Index (ex. Food & Energy)**					
AR	4.704	1.881	1.334	1.164	1.065	0.958	0.295	0.418	0.626	0.828	0.954	1.036
ToT ex.oil	1.013	0.980	1.000	1.025	1.038	1.069	1.002	1.018	1.026	1.030	1.030	1.027
CBO&ToT ex. oil	1.029	1.020^{*}	1.083	1.128	1.114	1.177	1.153	0.952	0.853	0.815	0.828	0.851
FRBD&ToT ex. oil	0.905^{***}	0.871^{**}	0.810^{**}	0.794^{**}	0.805^{**}	0.866^{*}	1.393	0.954^{**}	0.773^{**}	0.710^{**}	0.690^{**}	0.691^{**}
IMF&ToT ex. oil	1.039	1.009^{*}	1.054	1.076	1.057	1.120	1.073	1.125	1.122	1.096	1.081	1.076
OECD&ToT ex. oil	1.021	1.013^{*}	1.076	1.127	1.114	1.165	1.026	0.784^{***}	0.729^{***}	0.737^{**}	0.768^{**}	0.793^{*}
HP-filt.& ToT ex. oil	1.023	1.032	1.092	1.127	1.106	1.153	1.103	0.873^{**}	0.821^{**}	0.824^{**}	0.852^{*}	0.872^{*}
US Money&ToT ex. oil	1.041	1.027	1.075	1.137	1.119	1.159	1.062	1.068	1.112	1.144	1.167	1.194
G7 Money&ToT ex. oil	1.040	0.883^{**}	0.937^{**}	0.990	0.933^{*}	0.928^{*}	1.036	0.966^{*}	0.895^{**}	0.920^{*}	0.960	0.975
	PCE Chain Price Index						**Trimmed Mean PCE Price Index**					
AR	2.329	1.190	0.930	0.885	0.875	0.899	0.142	0.169	0.229	0.313	0.386	0.436
ToT ex.oil	1.043	1.036	1.039	1.065	1.076	1.083	1.008	1.045	1.046	1.047	1.047	1.040
CBO&ToT ex. oil	1.057	1.075	1.080	1.119	1.096	1.102	0.968	0.938	0.936	0.940	0.966	0.978
FRBD&ToT ex. oil	0.941^{***}	0.981^{*}	0.938^{*}	0.946	0.943	0.964	0.925^{***}	0.907^{**}	0.854^{**}	0.843^{**}	0.850^{**}	0.831^{*}
IMF&ToT ex. oil	1.057	1.053	1.045	1.076	1.054	1.065	1.033	0.954^{**}	0.886^{**}	0.869^{**}	0.860^{**}	0.855^{*}
OECD& ToT ex. oil	1.052	1.069	1.071	1.109	1.083	1.084	0.913^{***}	0.841^{**}	0.872^{**}	0.903^{*}	0.941^{*}	0.964
HP-filt.& ToT ex. oil	1.059	1.077	1.071	1.108	1.082	1.083	0.938^{***}	0.961^{**}	0.984^{*}	0.987	1.009	1.006
US Money&ToT ex. oil	1.075	1.073	1.085	1.136	1.109	1.165	0.997	1.127	1.117	1.127	1.142	1.139
G7 Money&ToT ex. oil	1.088	0.942^{**}	0.980^{*}	0.996	0.915^{*}	0.916^{*}	1.055	1.217	1.364	1.393	1.414	1.304
	GDP Deflator						**Producer Price Index**					
AR	0.508	0.376	0.423	0.498	0.545	0.575	19.431	7.829	4.724^{*}	3.127	2.207	1.786
ToT ex. oil	0.993	1.061	1.049	1.056	1.058	1.063	1.035	0.981	0.949	0.982	1.051	1.152
CBO&ToT ex. oil	0.917^{***}	0.819^{**}	0.886^{**}	0.970	1.016	1.057	1.051	0.988^{*}	0.967^{*}	1.012	1.118	1.224
FRBD&ToT ex. oil	0.891^{***}	0.895^{**}	0.920^{*}	0.948^{*}	0.976	0.999	1.078	1.047^{*}	1.033^{*}	1.089	1.191	1.293
IMF&ToT ex. oil	1.013	1.093	1.073	1.055	1.052	1.064	1.070	1.010^{*}	0.992^{*}	1.053^{*}	1.173	1.306
OECD&ToT ex. oil	0.881^{***}	0.779^{***}	0.858^{**}	0.955^{*}	1.007	1.047	1.039	0.963^{*}	0.935^{*}	0.977	1.073	1.153
HP-filt.&ToT ex. oil	0.917^{***}	0.874^{**}	0.925^{*}	0.991	1.043	1.079	1.044	0.985	0.965	1.031	1.151	1.271
US Money&ToT ex. oil	1.000	1.110	1.099	1.106	1.108	1.125	1.082	0.997^{*}	0.959^{*}	1.024	1.128	1.249
G7 Money&ToT ex. oil	0.988^{*}	1.042	1.038	1.037	1.022	1.026	1.109	0.967^{**}	0.930^{**}	0.991^{*}	1.086	1.162

Table B.4: Benchmark sample forecasts with domestic variables and terms of trade ex. oil

See the note in the previous table.

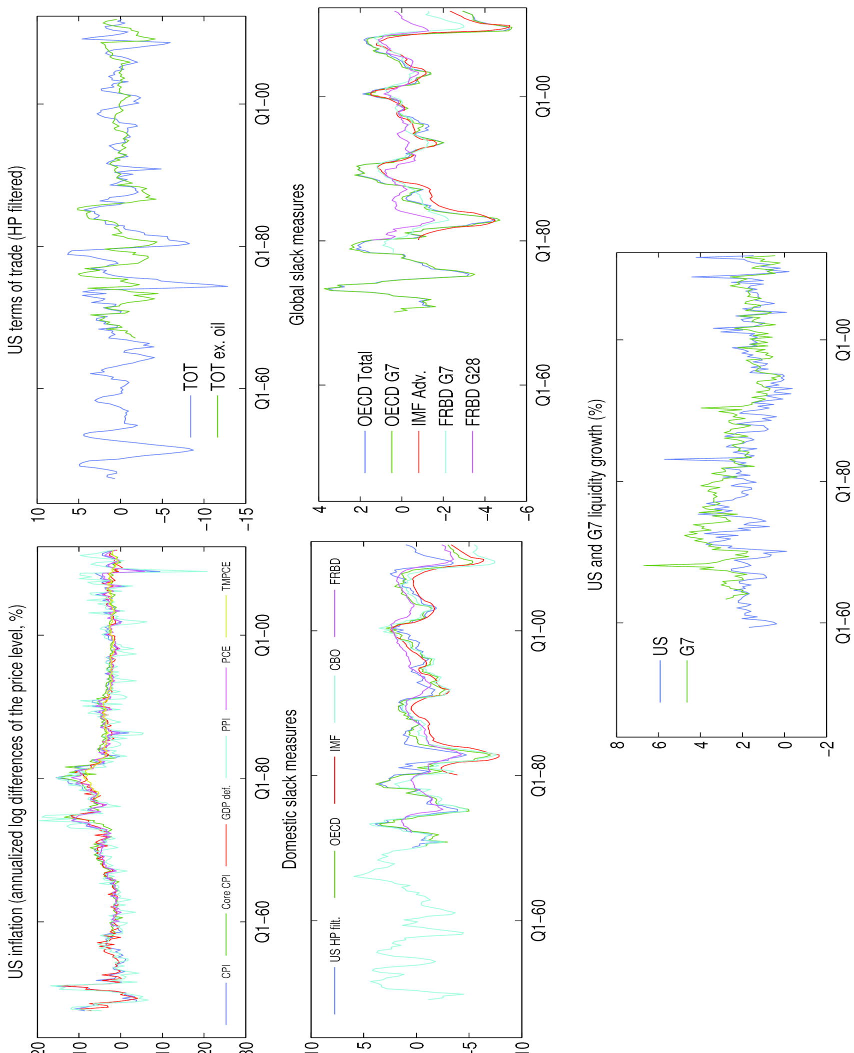

Figure B.1: Time series plots of the data

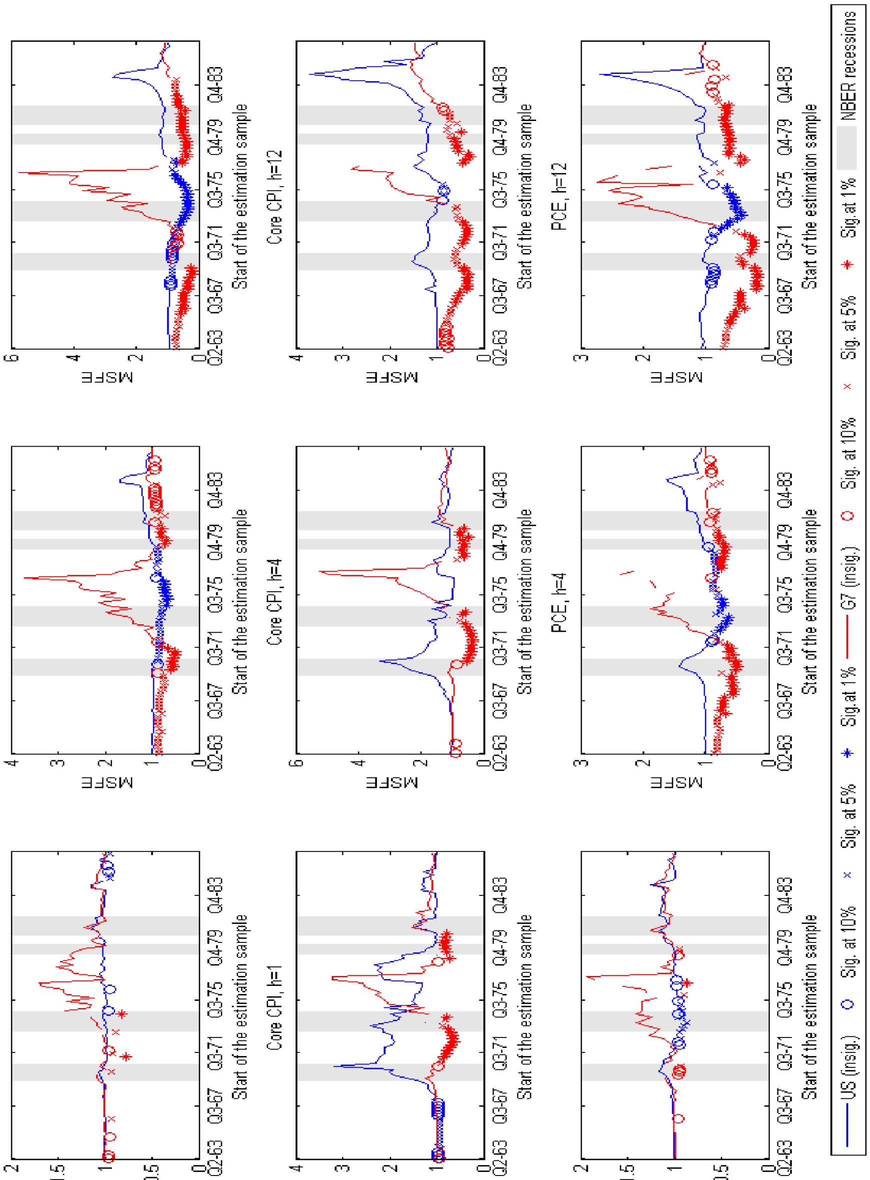

Figure B.2: Evolution of the relative MSFEs of the forecasts with the US vs. G7 money growth

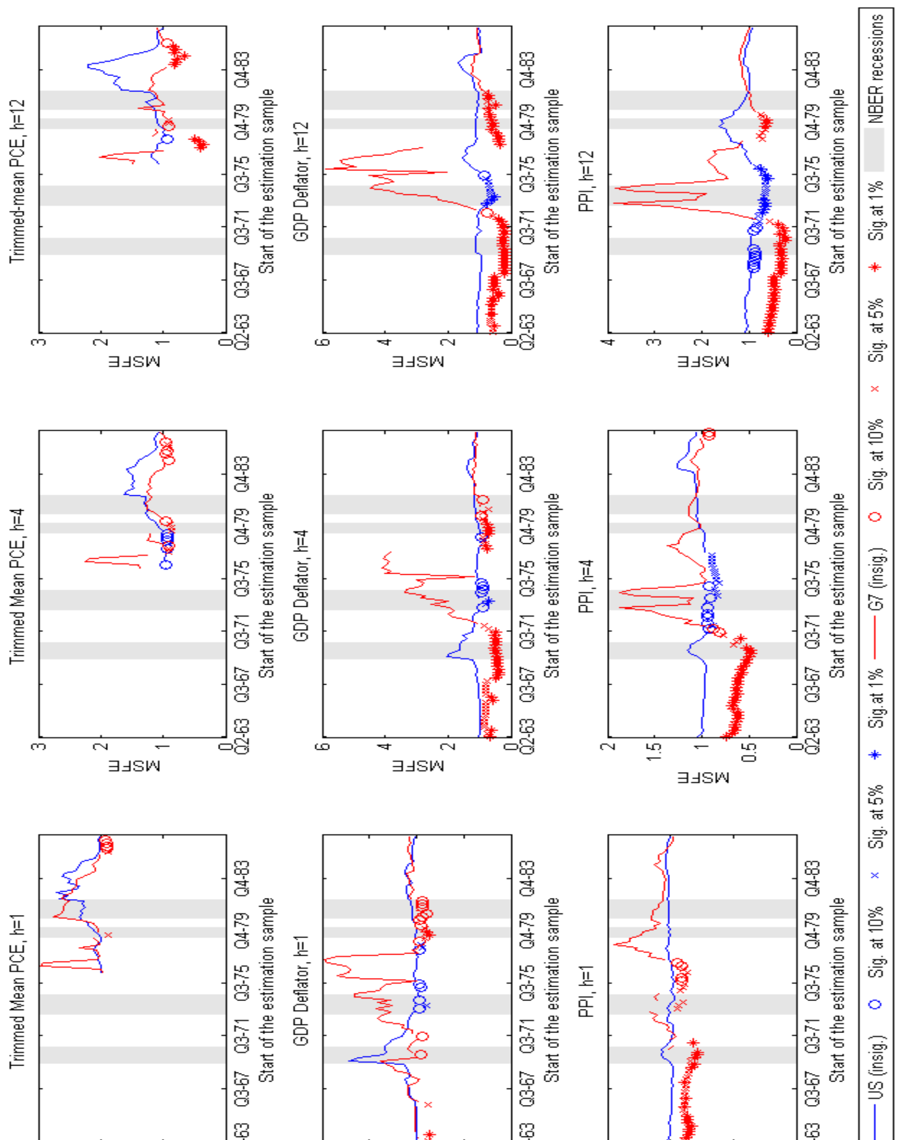

Figure B.3: Evolution of the relative MSFEs of the forecasts with the US vs. G7 money growth

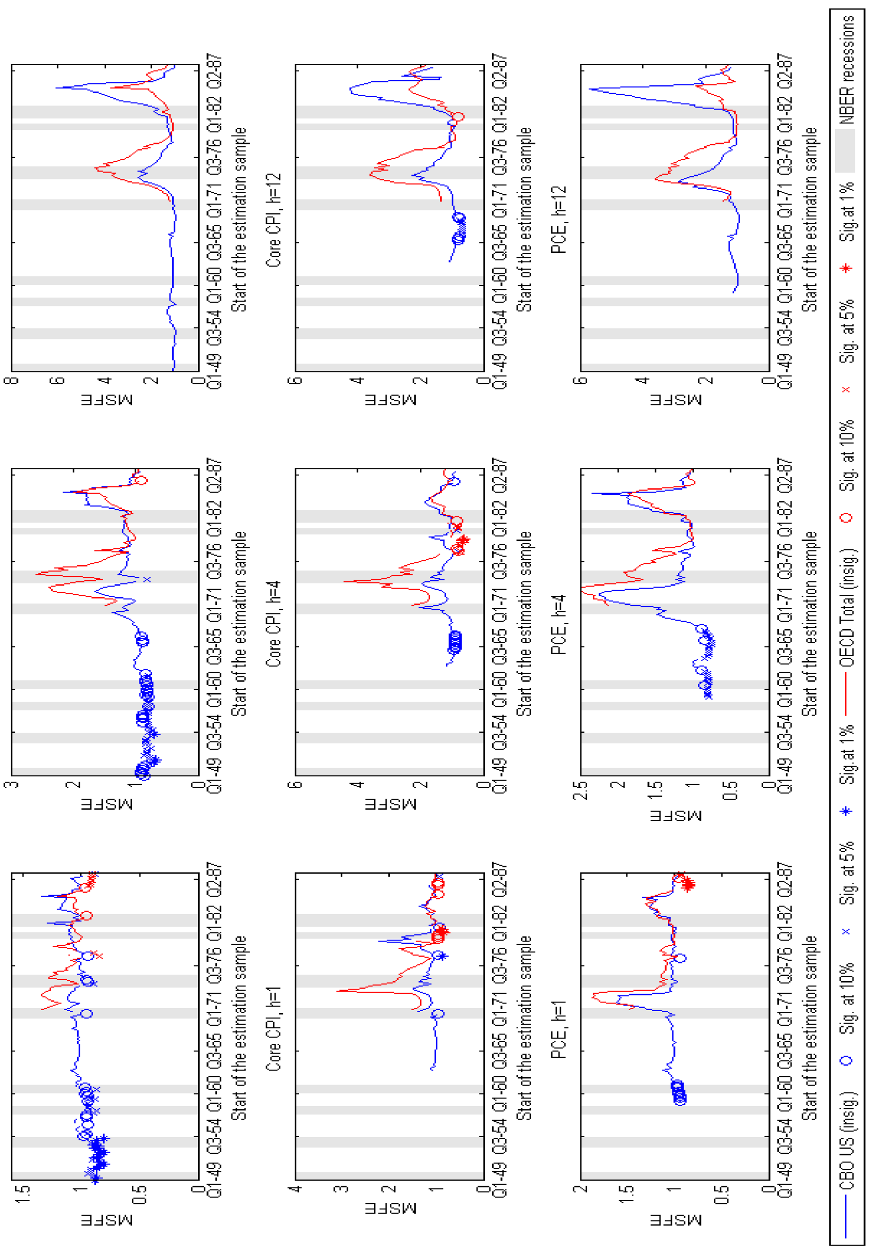

Figure B.4: Evolution of the relative MSFEs of the forecasts with the CBO US slack vs. OECD Total slack

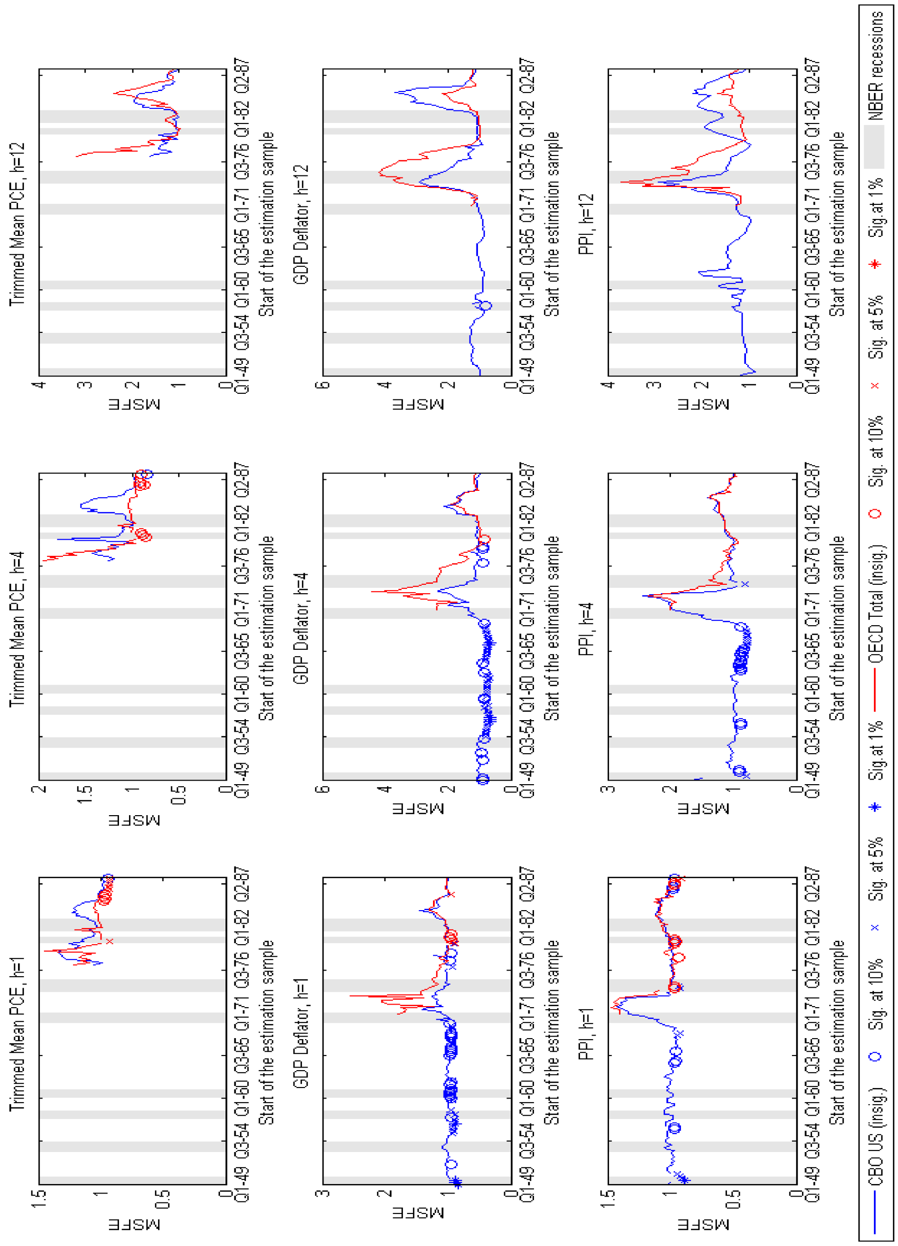

Figure B.5: Evolution of the relative MSFEs of the forecasts with the CBO US slack vs. OECD Total slack

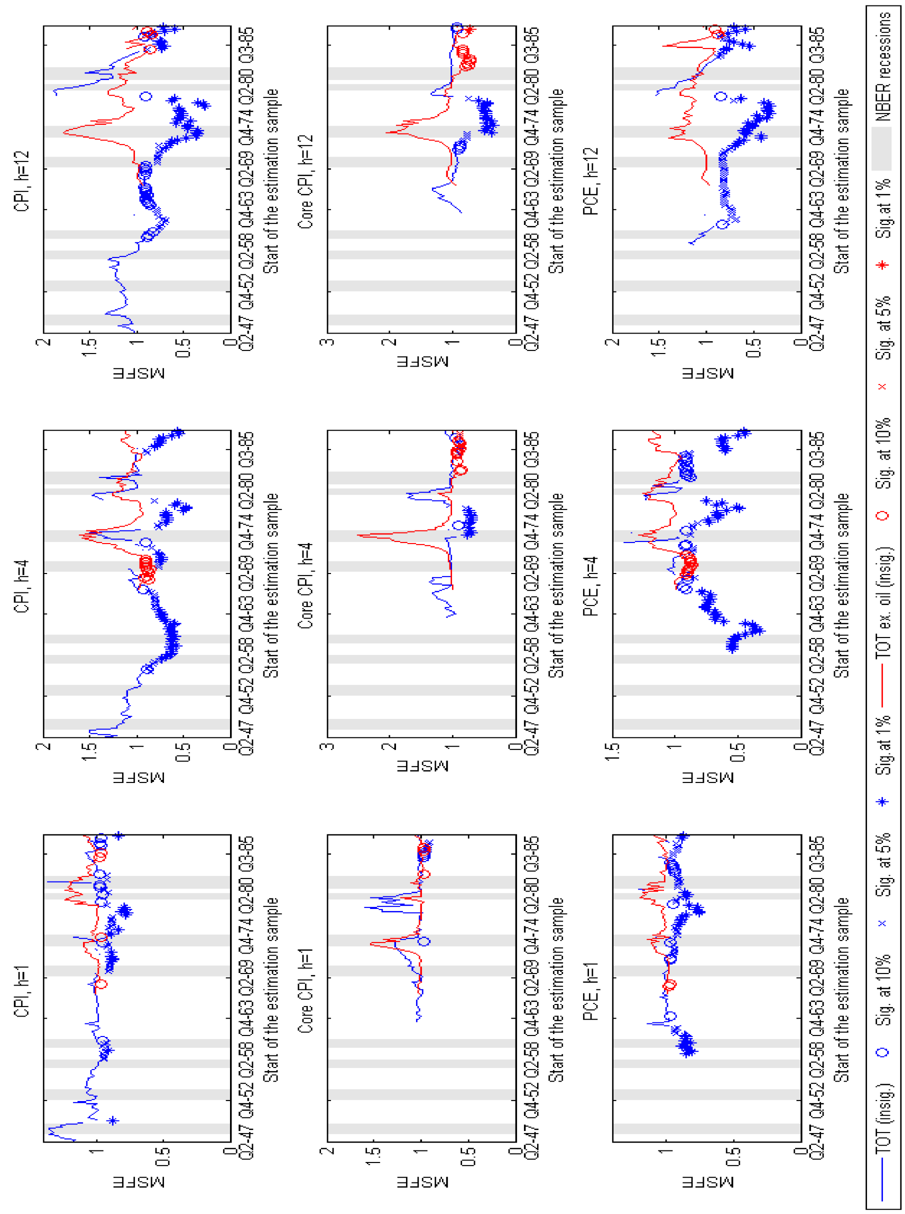

Figure B.6: Evolution of the relative MSFEs of the forecasts with terms of trade vs. terms of trade ex. oil

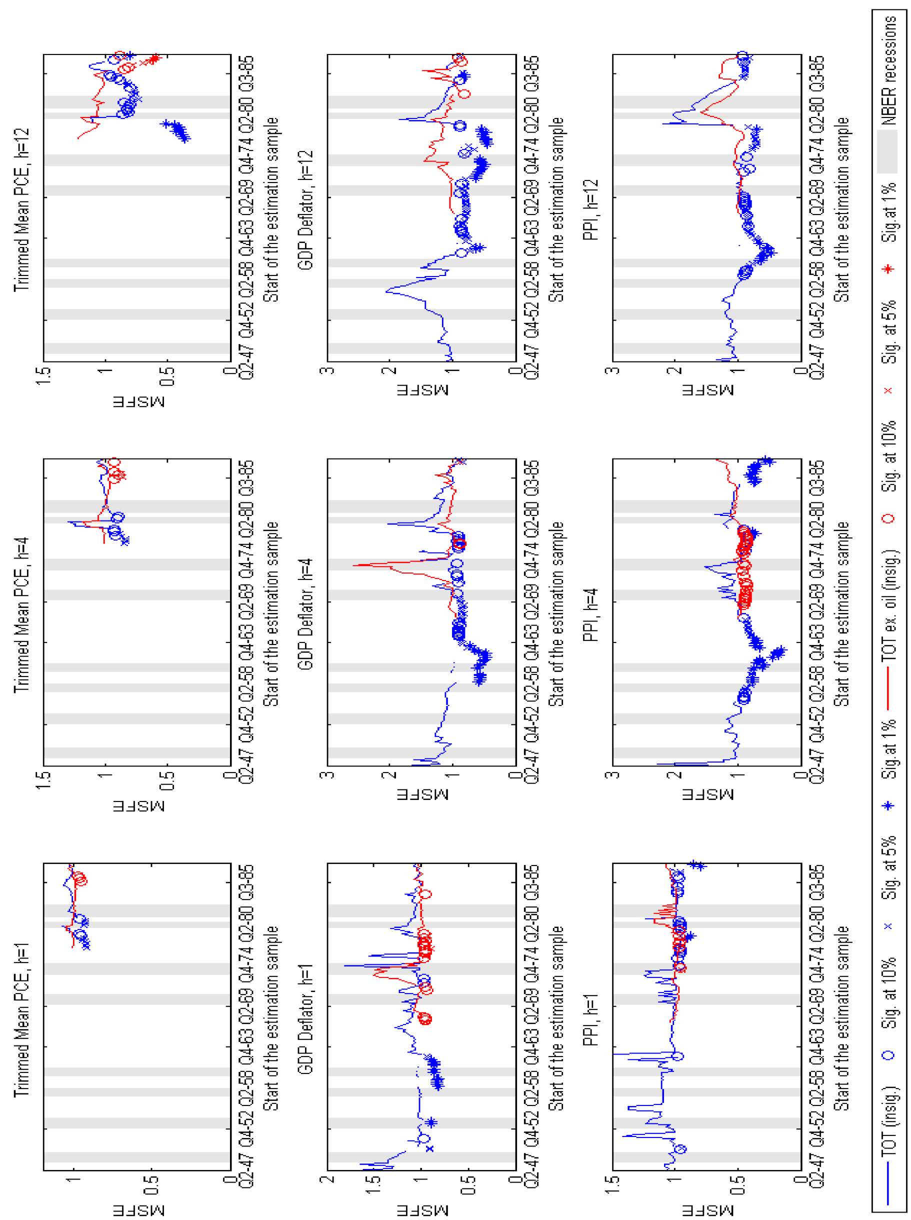

Figure B.7: Evolution of the relative MSFEs of the forecasts with terms of trade vs. terms of trade ex. oil

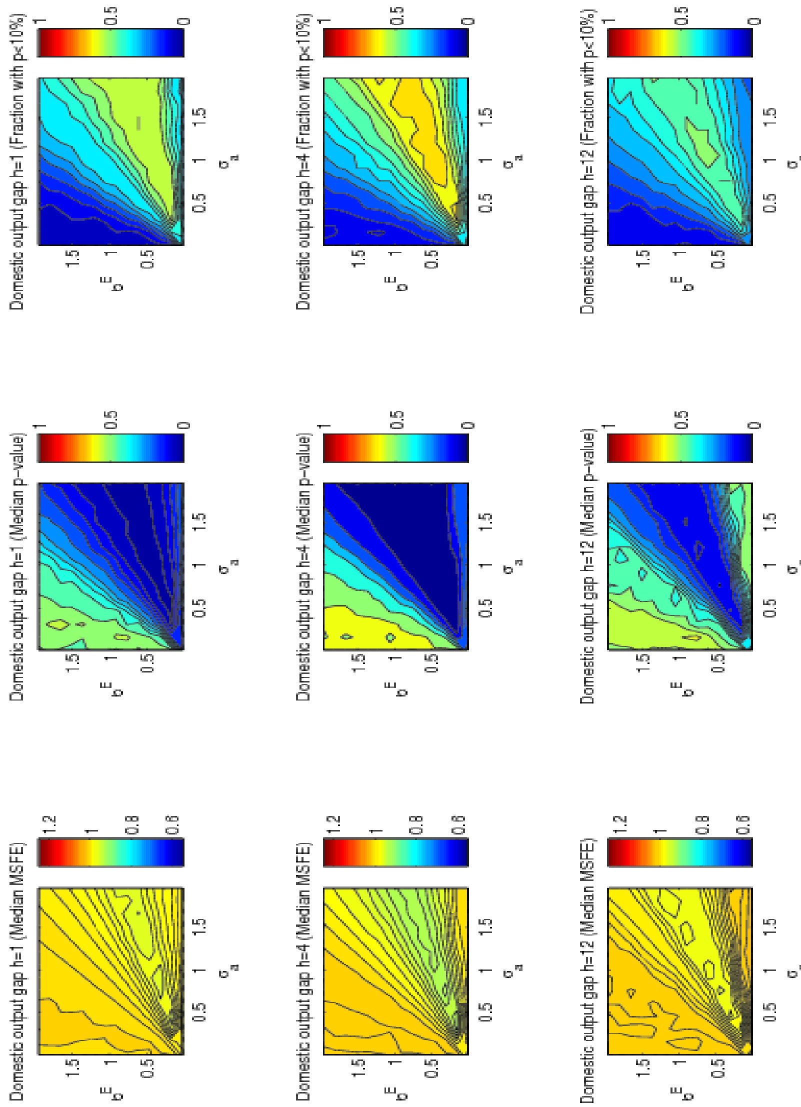

Figure B.8: Model's prediction of the relative MSFEs of forecasts with domestic slack - good luck

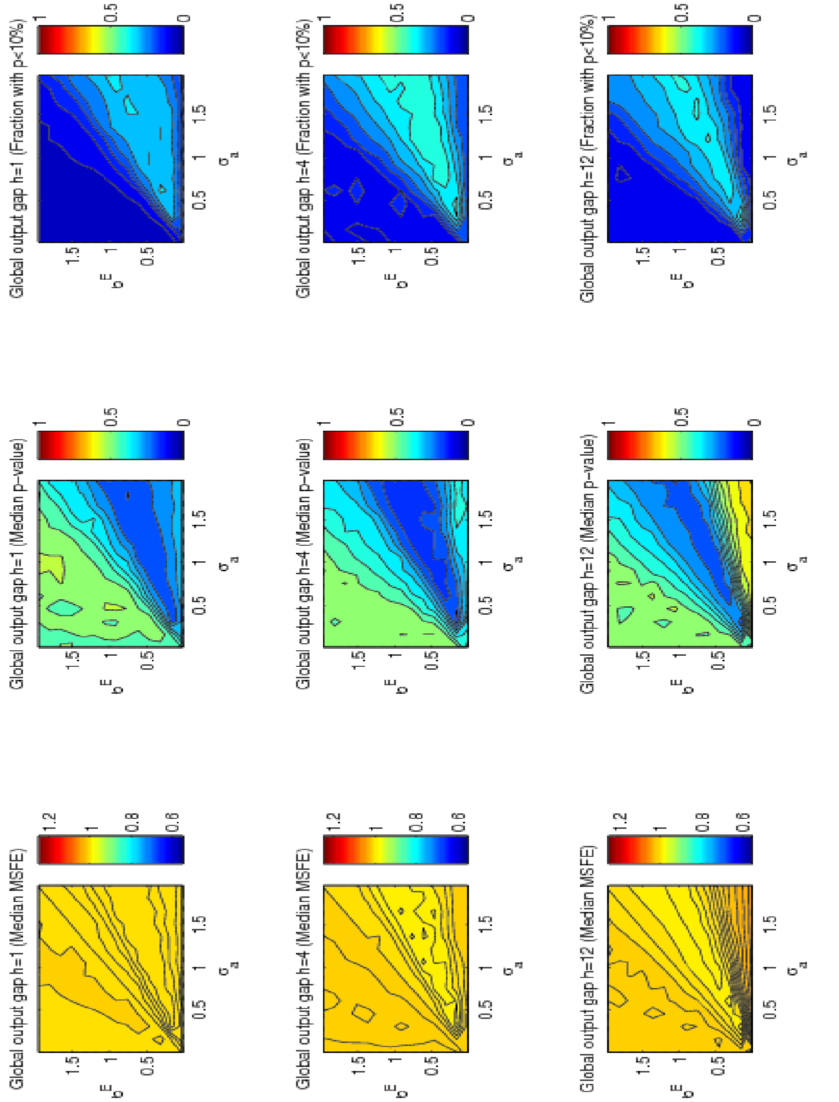

Figure B.9: Model's prediction of the relative MSFEs of forecasts with global slack - good luck

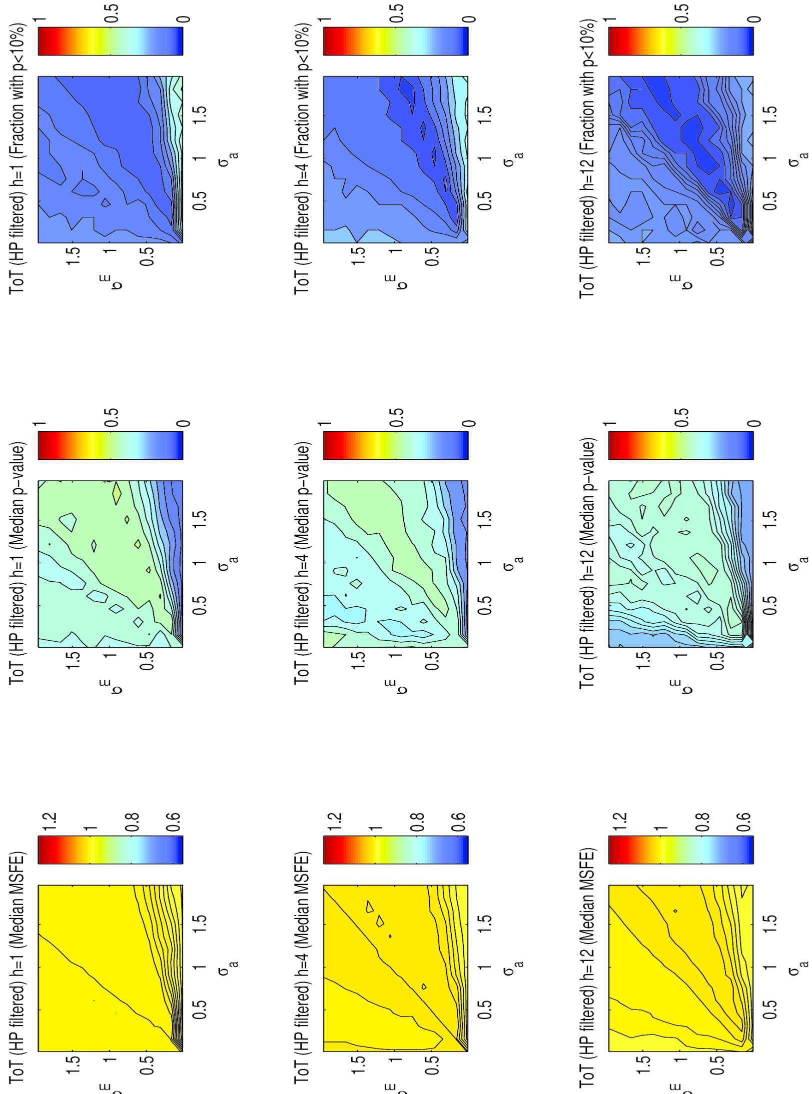

Figure B.10: Model's prediction of the relative MSFEs of forecasts with HP-filtered ToT - good luck

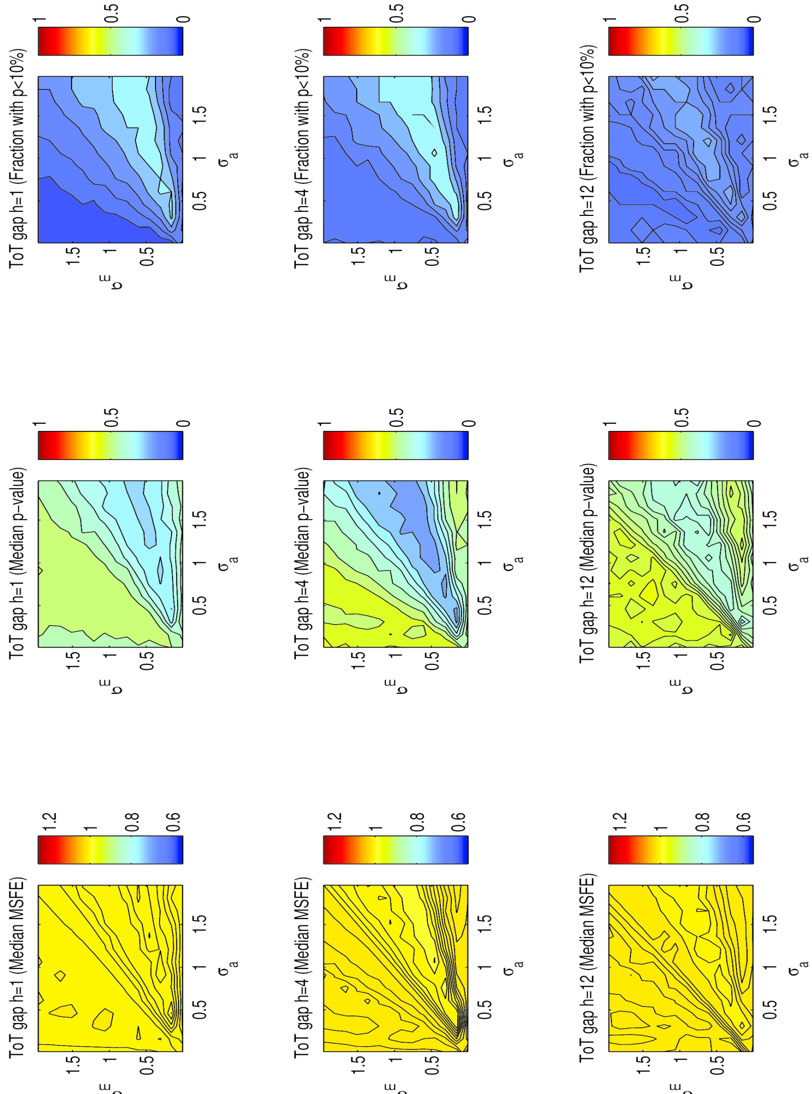

Figure B.11: Model's prediction of the relative MSFEs of forecasts with ToT gap- good luck

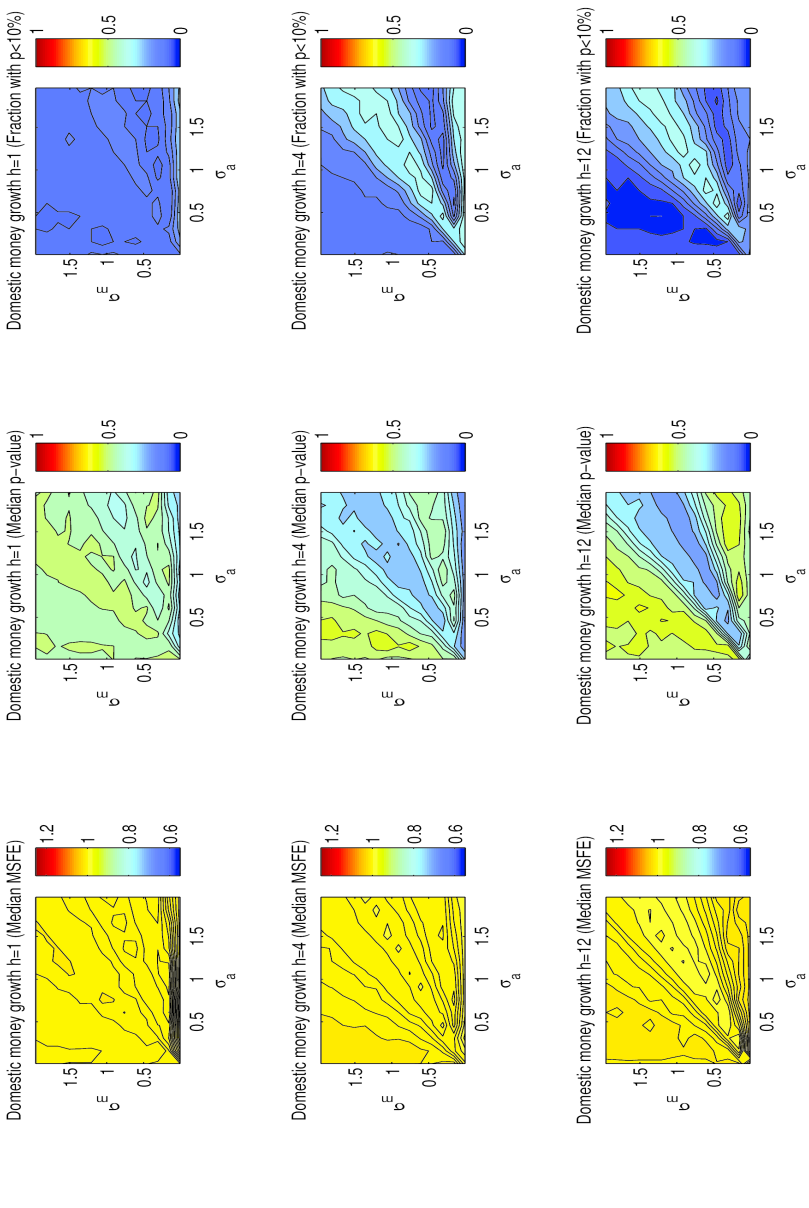

Figure B.12: Model's prediction of the relative MSFEs of forecasts with domestic money-good luck

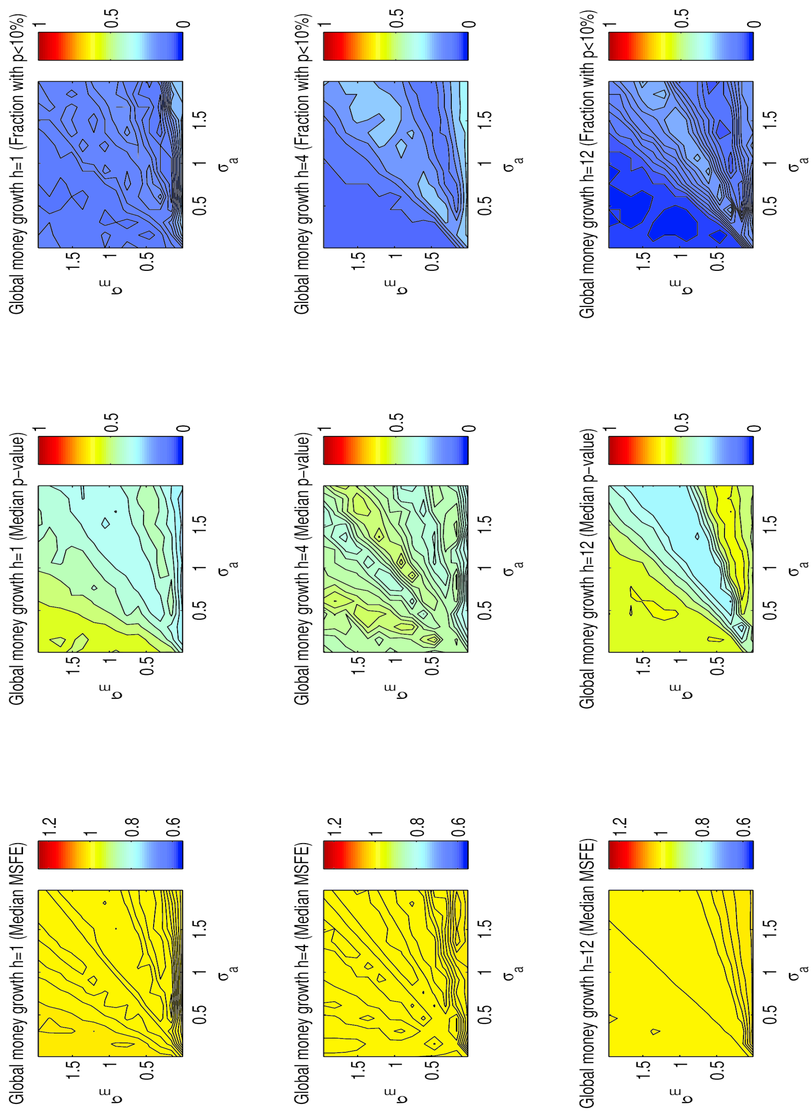

Figure B.13: Model's prediction of the relative MSFEs of forecasts with global money - good luck

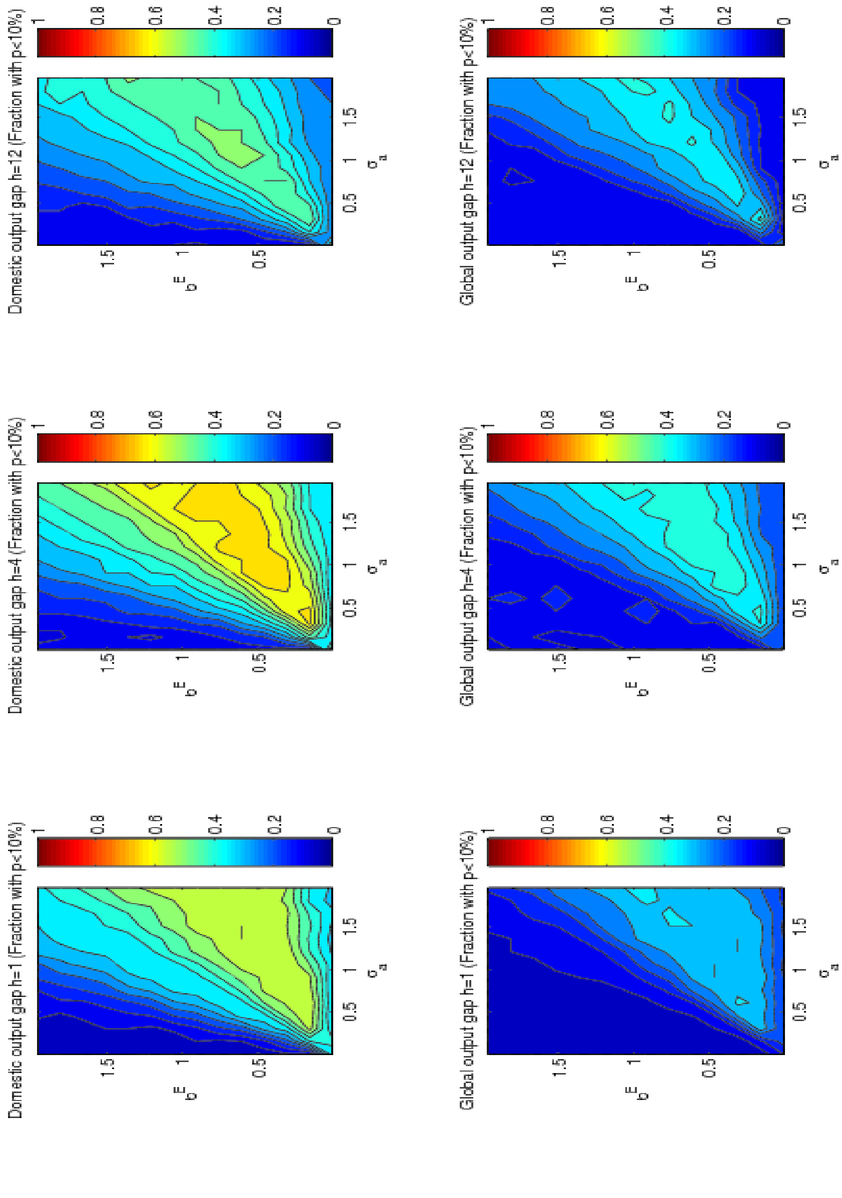

Figure B.14: Comparison of the forecasting performances of simulated domestic and global output gap - good luck

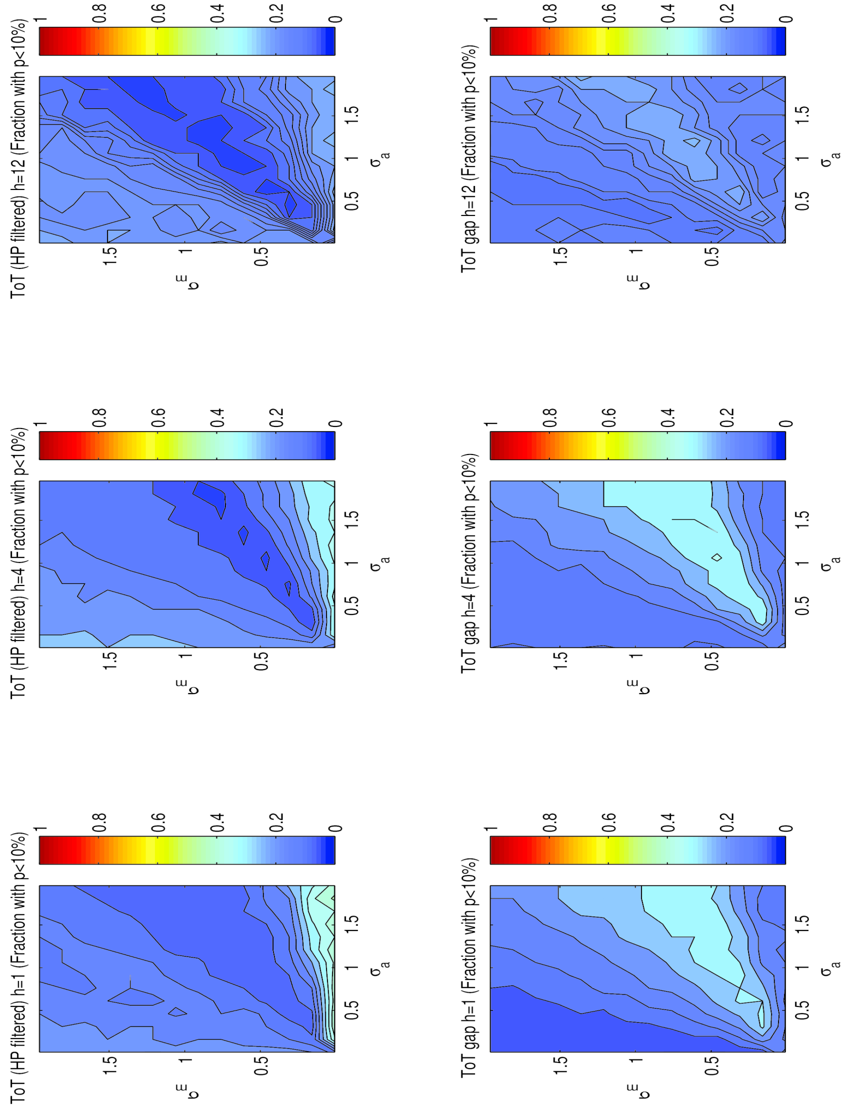

Figure B.15: Comparison of the forecasting performances of simulated HP-filtered ToT and ToT gap - good luck

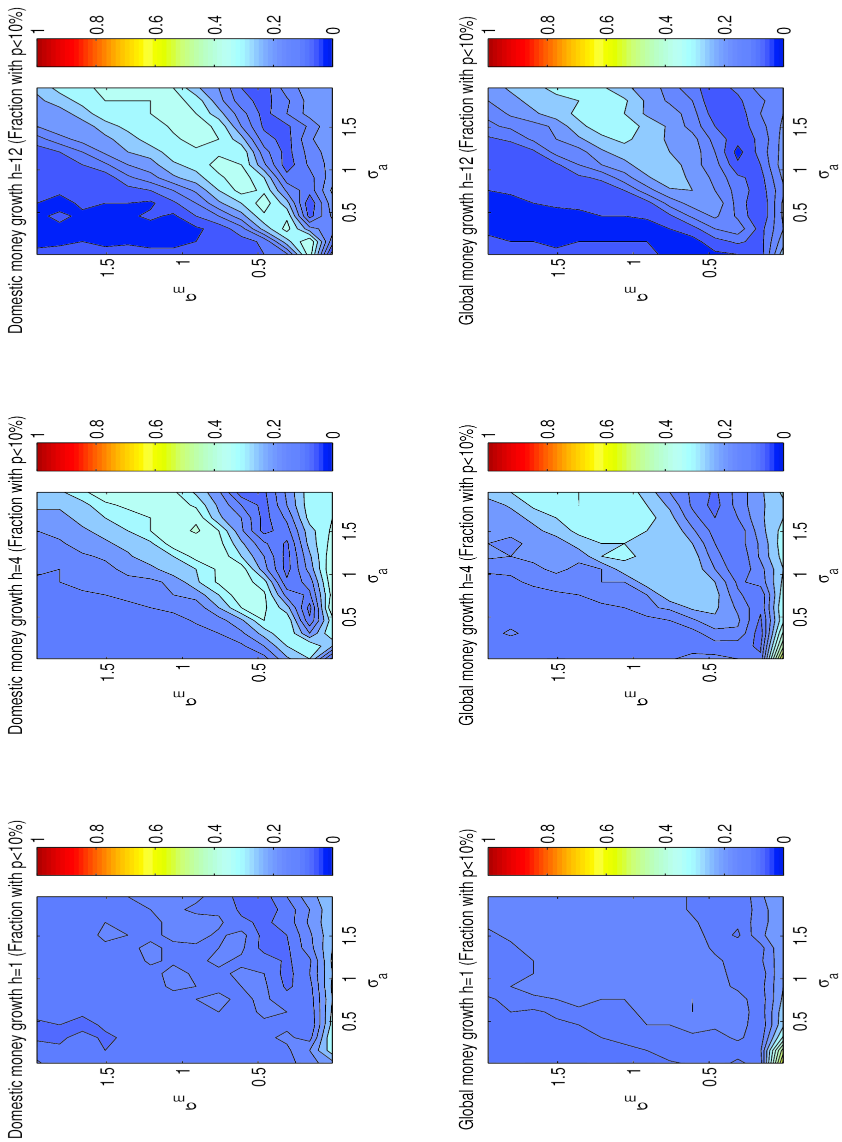

Figure B.16: Comparison of the forecasting performances of simulated domestic and global money - good luck

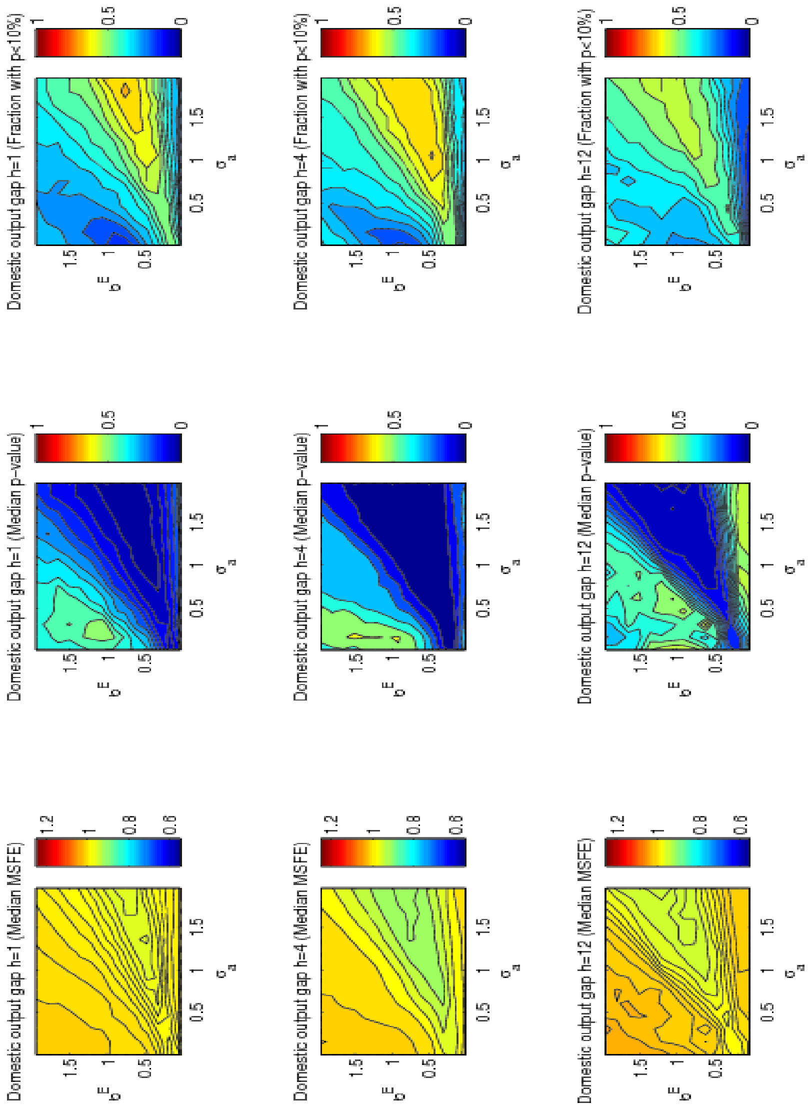

Figure B.17: Model's prediction of the relative MSFEs of forecasts with domestic slack - good luck (asymmetric)

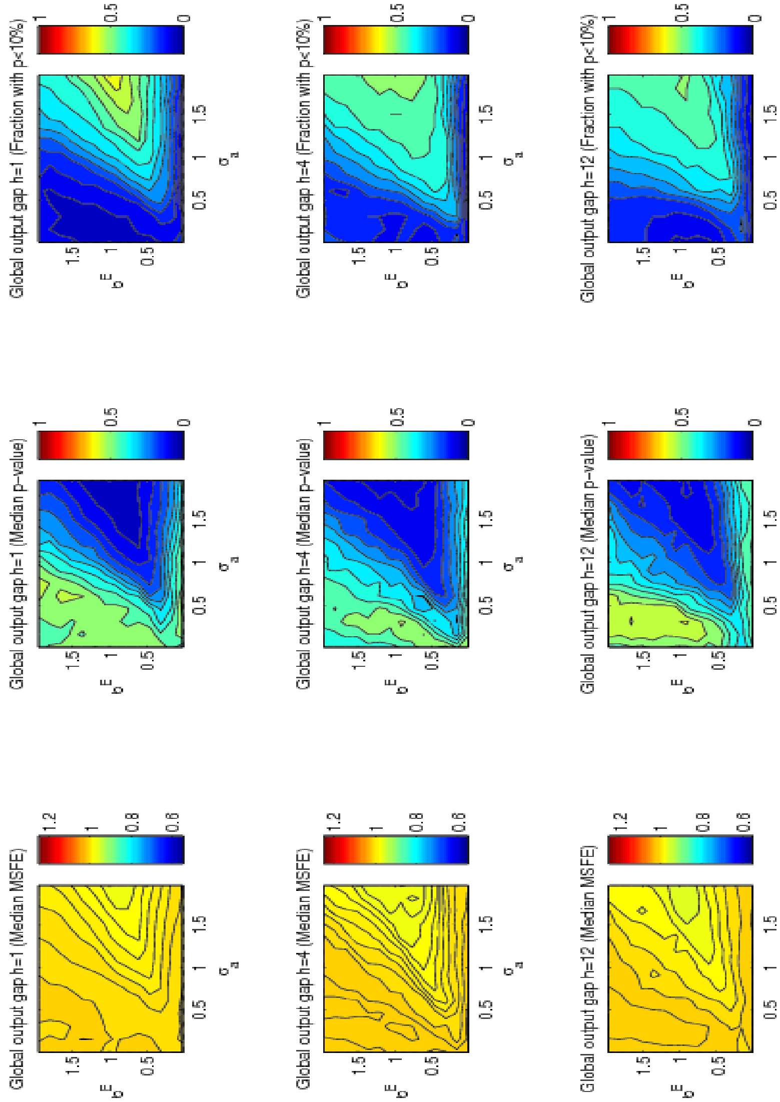

Figure B.18: Model's prediction of the relative MSFEs of forecasts with global slack - good luck (asymmetric)

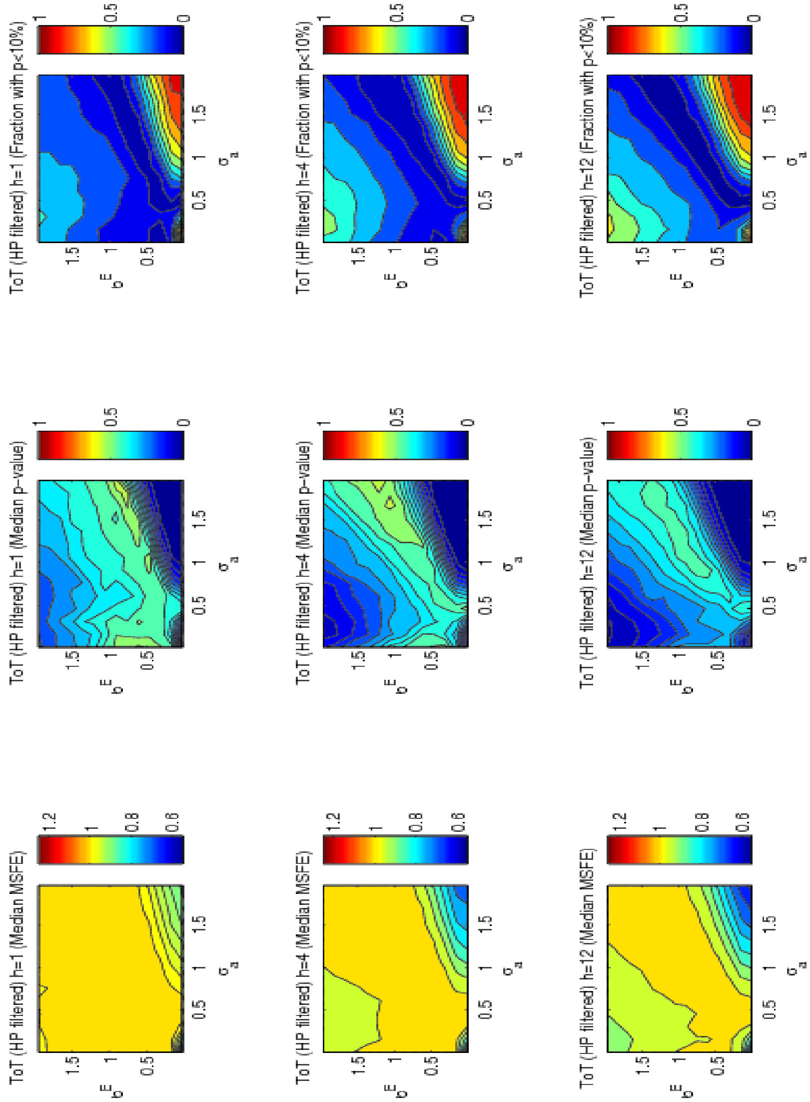

Figure B.19: Model's prediction of the relative MSFEs of forecasts with HP-filtered ToT - good luck (asymmetric)

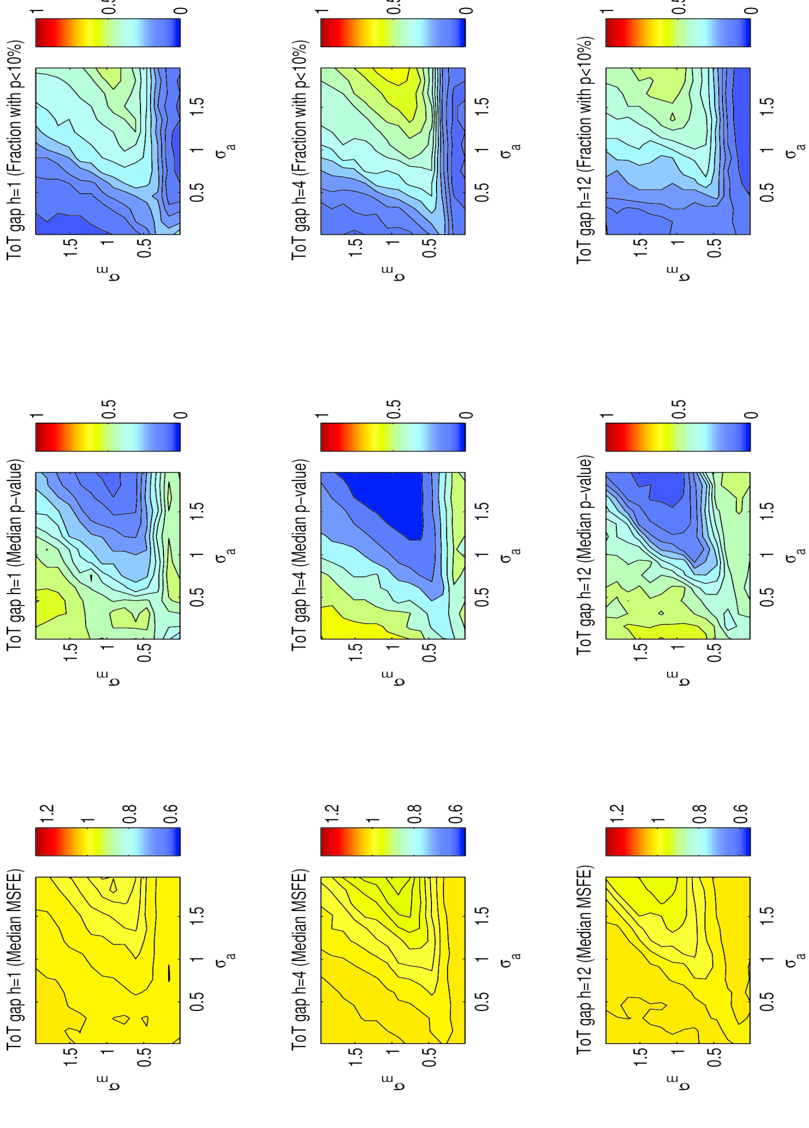

Figure B.20: Model's prediction of the relative MSFEs of forecasts with ToT gap- good luck (asymmetric)

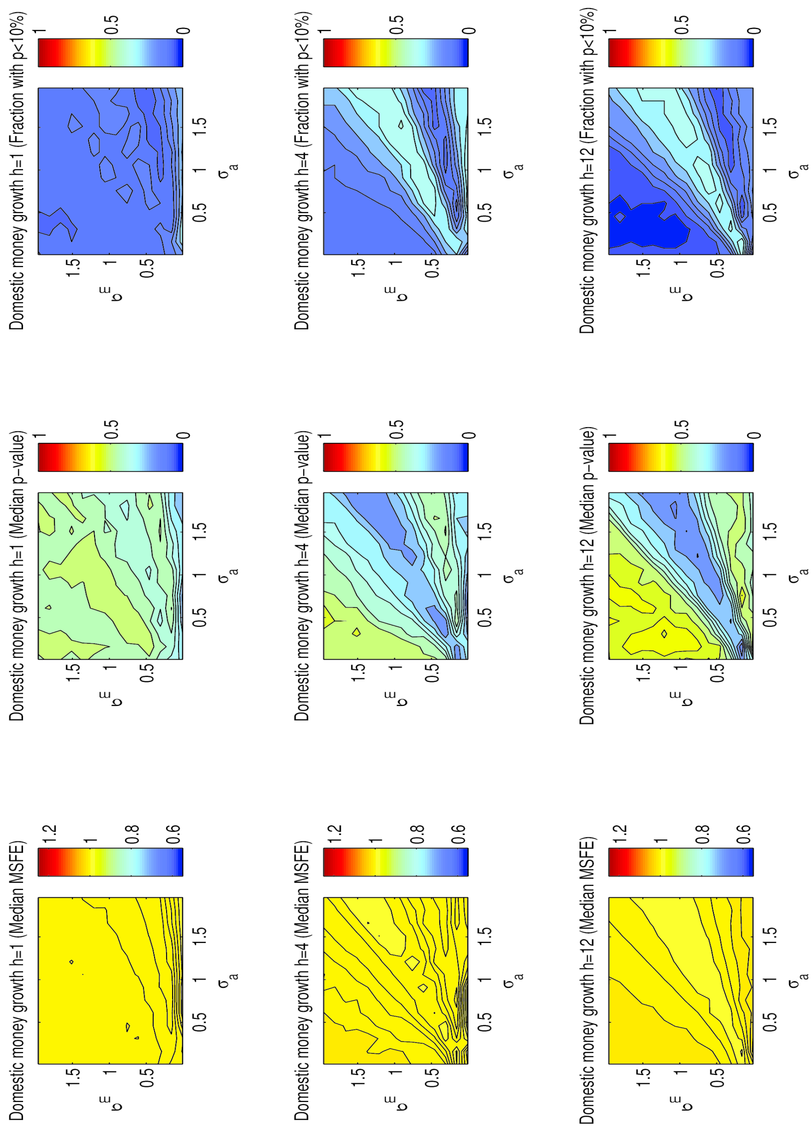

Figure B.21: Model's prediction of the relative MSFEs of forecasts with domestic money - good luck (asymmetric)

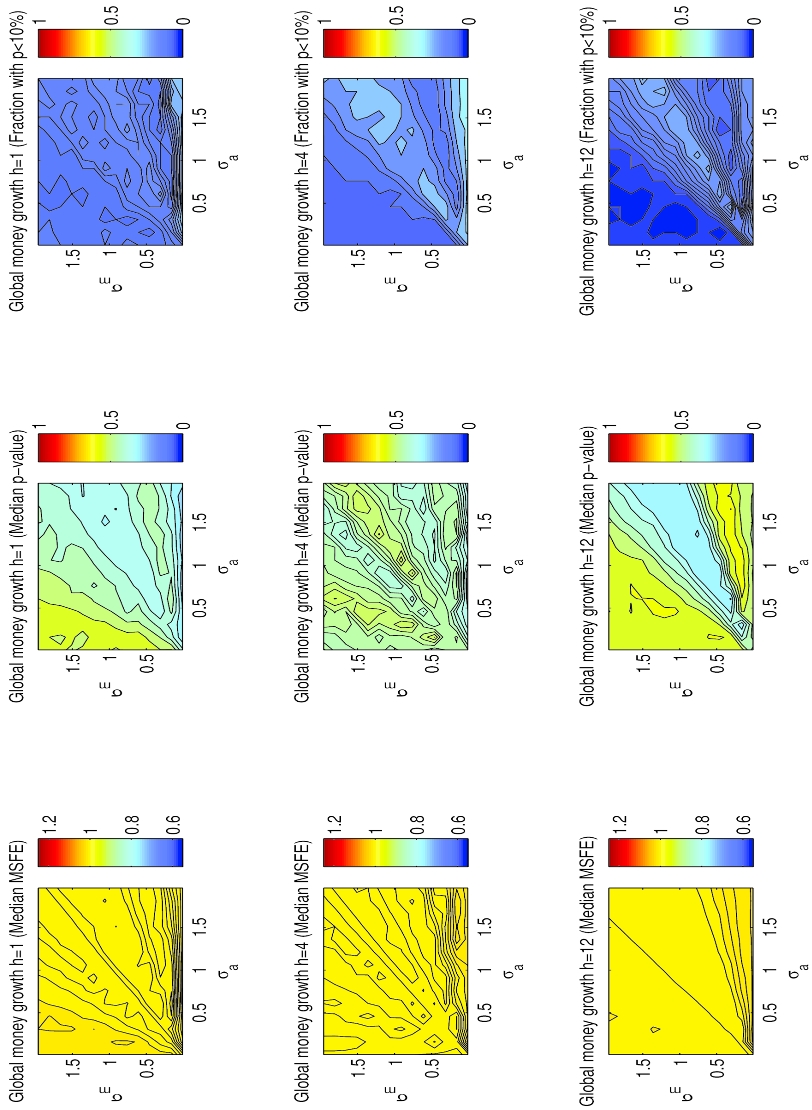

Figure B.22: Model's prediction of the relative MSFEs of forecasts with global money - good luck (asymmetric)

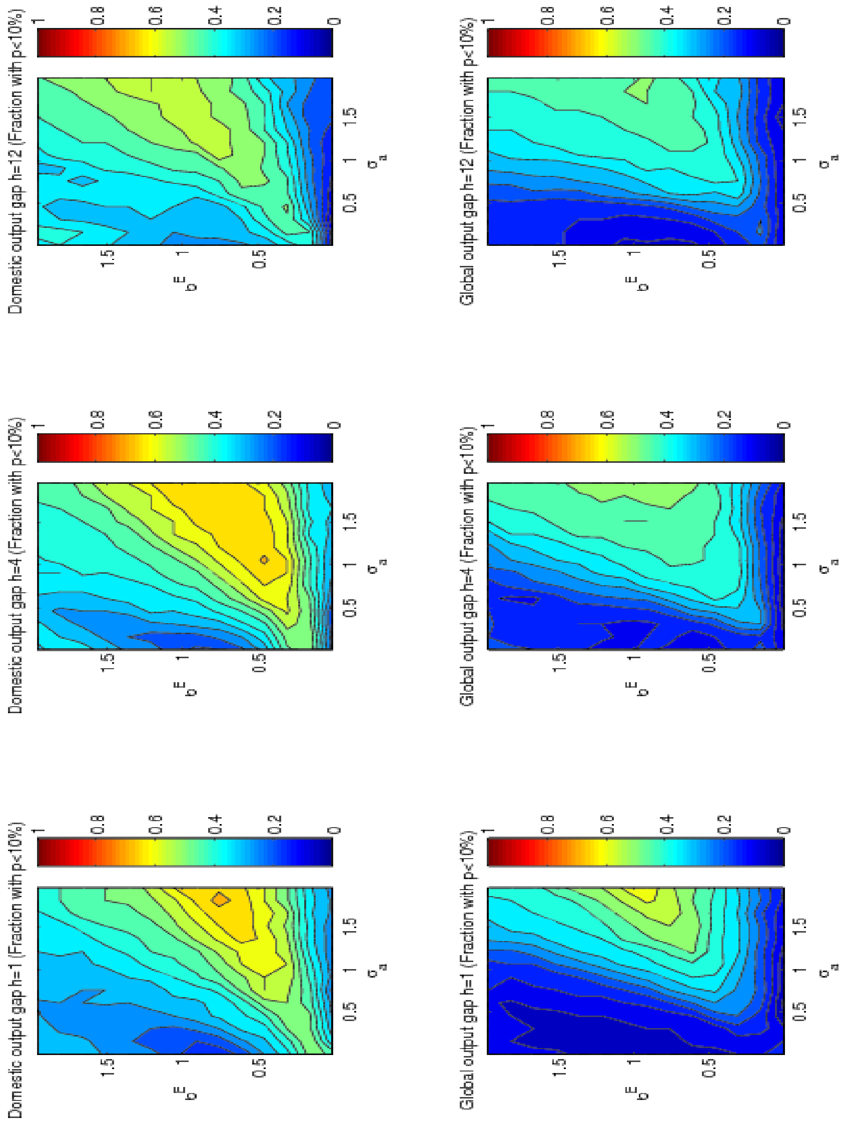

Figure B.23: Comparison of the forecasting performances of simulated domestic and global output gap - good luck (asymmetric)

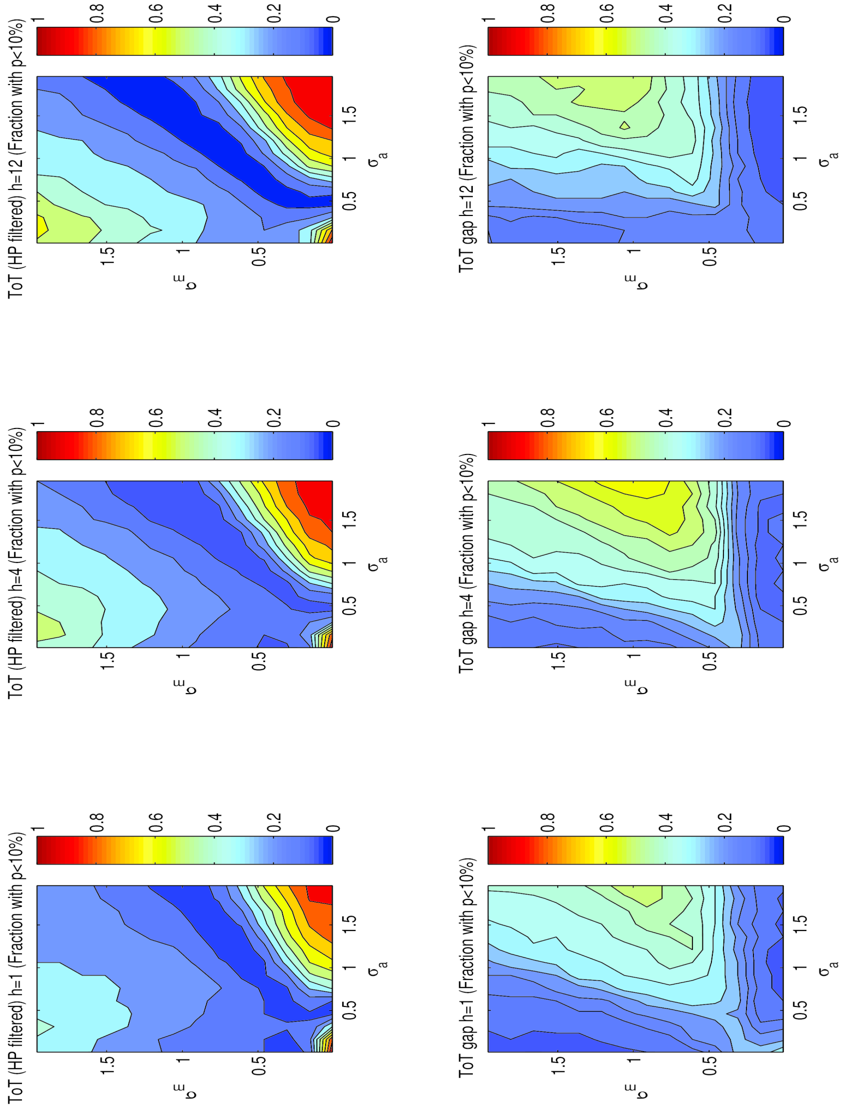

Figure B.24: Comparison of the forecasting performances of simulated HP-filtered ToT and ToT gap - good luck (asymmetric)

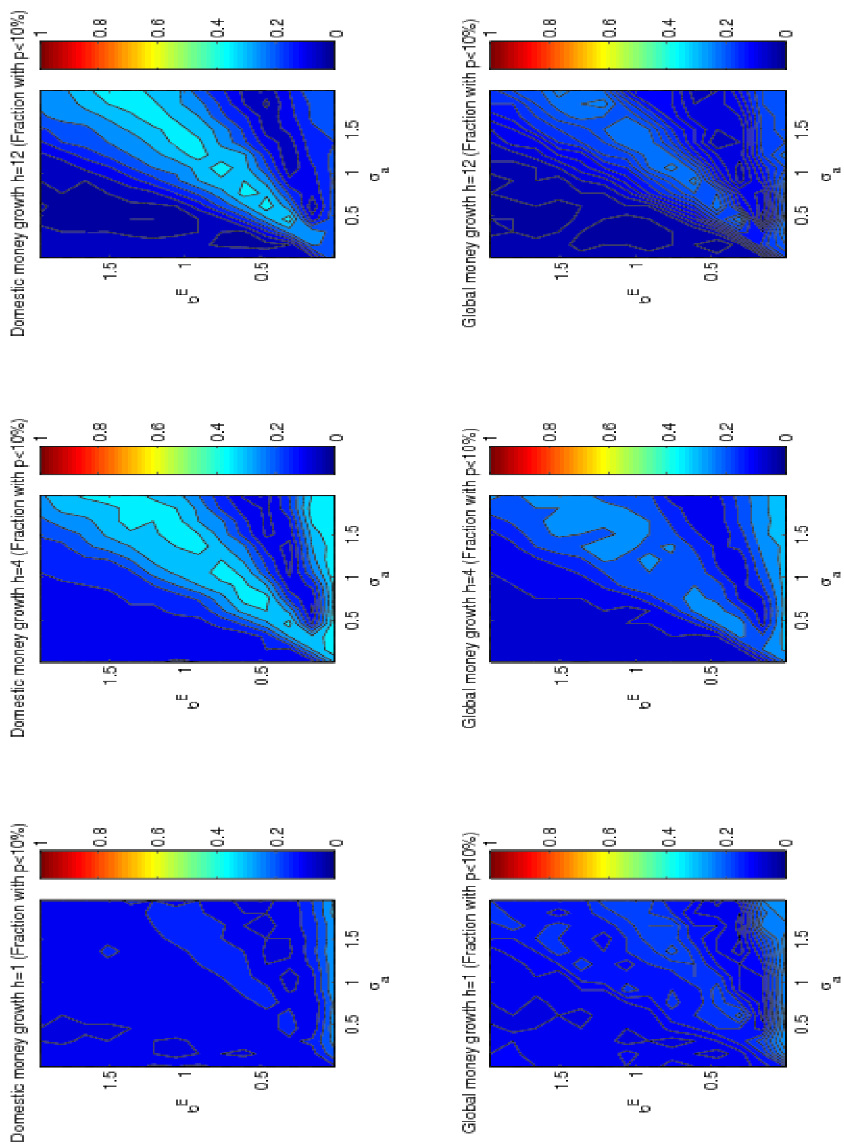

Figure B.25: Comparison of the forecasting performances of simulated domestic and global money- good luck (asymmetric)

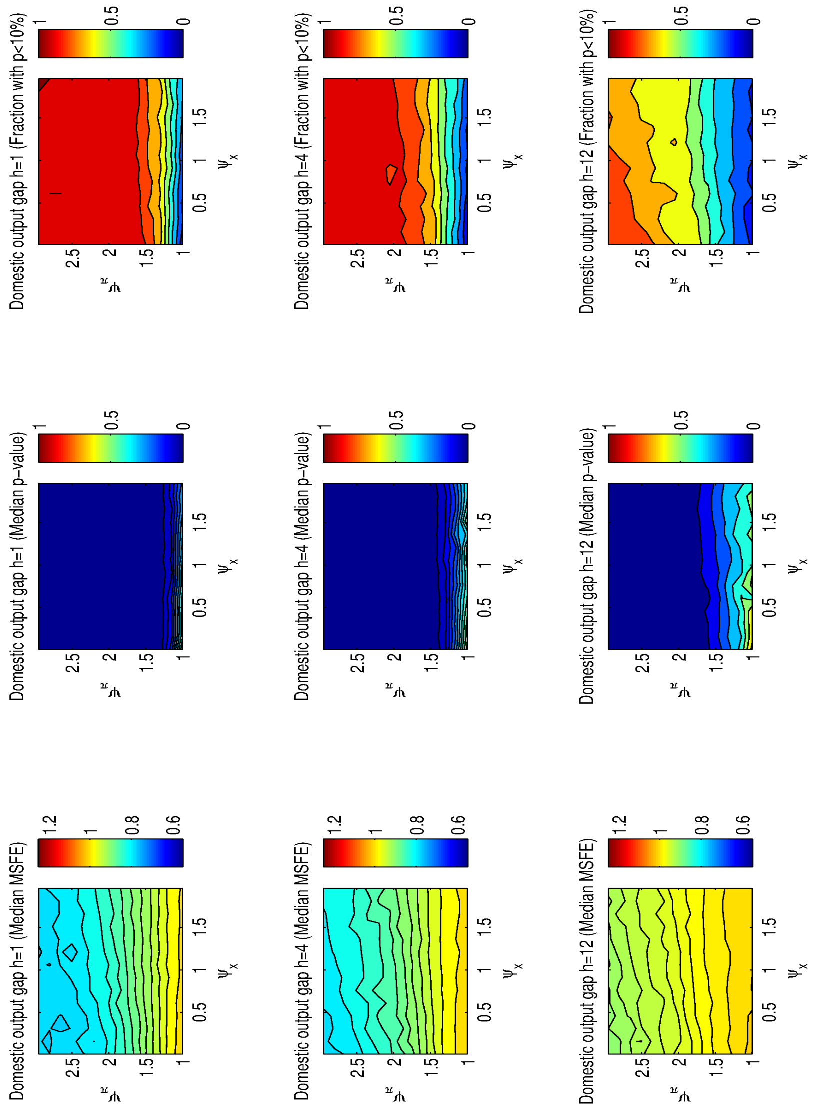

Figure B.26: Model's prediction of the relative MSFEs of forecasts with domestic slack - monetary policy (low inertia)

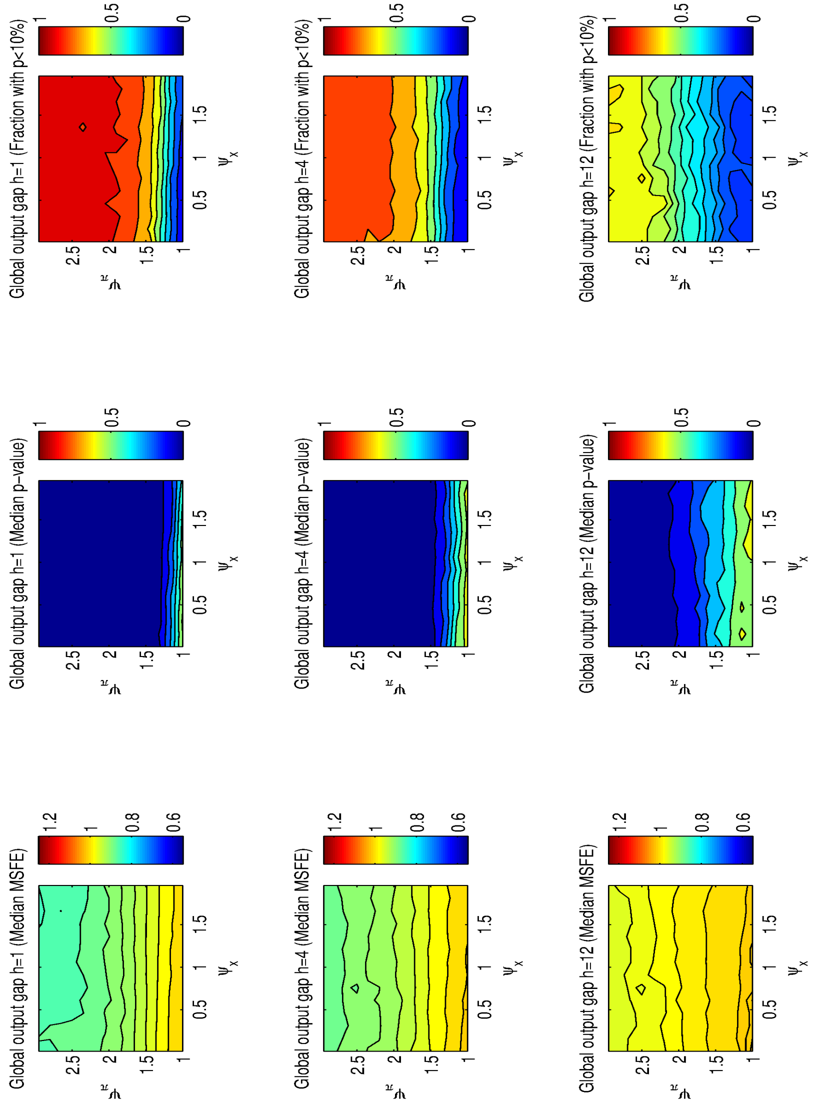

Figure B.27: Model's prediction of the relative MSFEs of forecasts with global slack - monetary policy (low inertia)

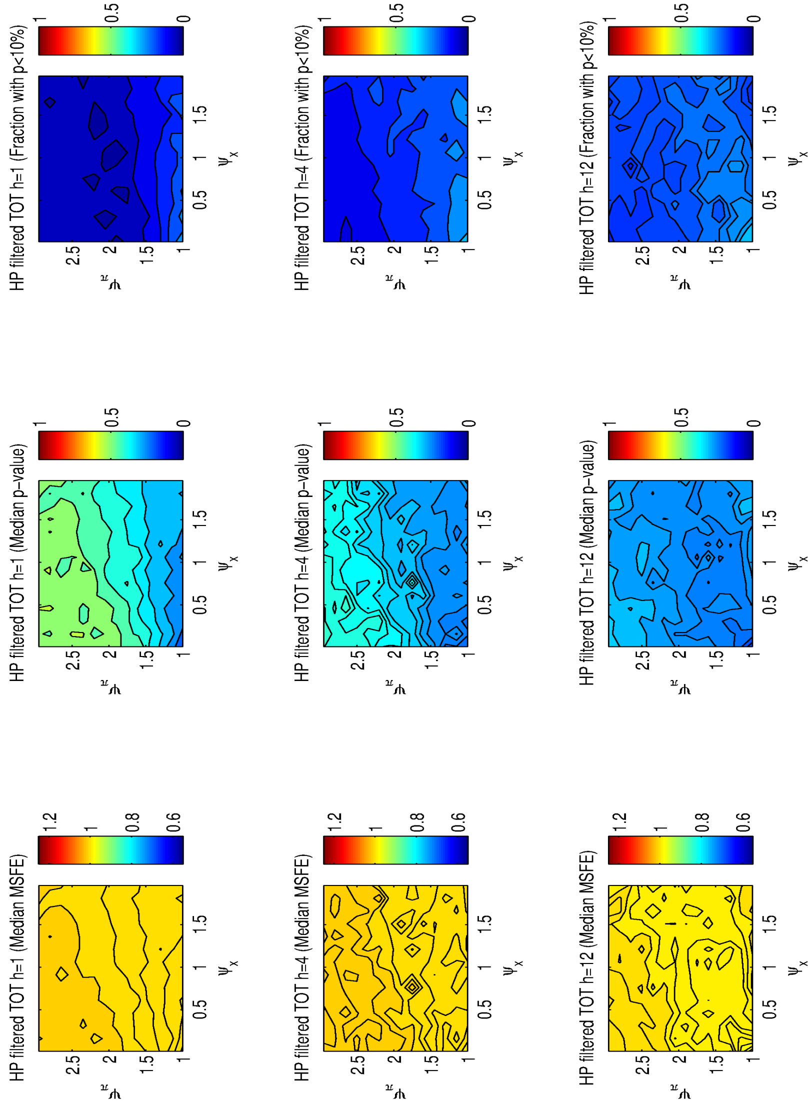

Figure B.28: Model's prediction of the relative MSFEs of forecasts with HP-filtered ToT - monetary policy (low inertia)

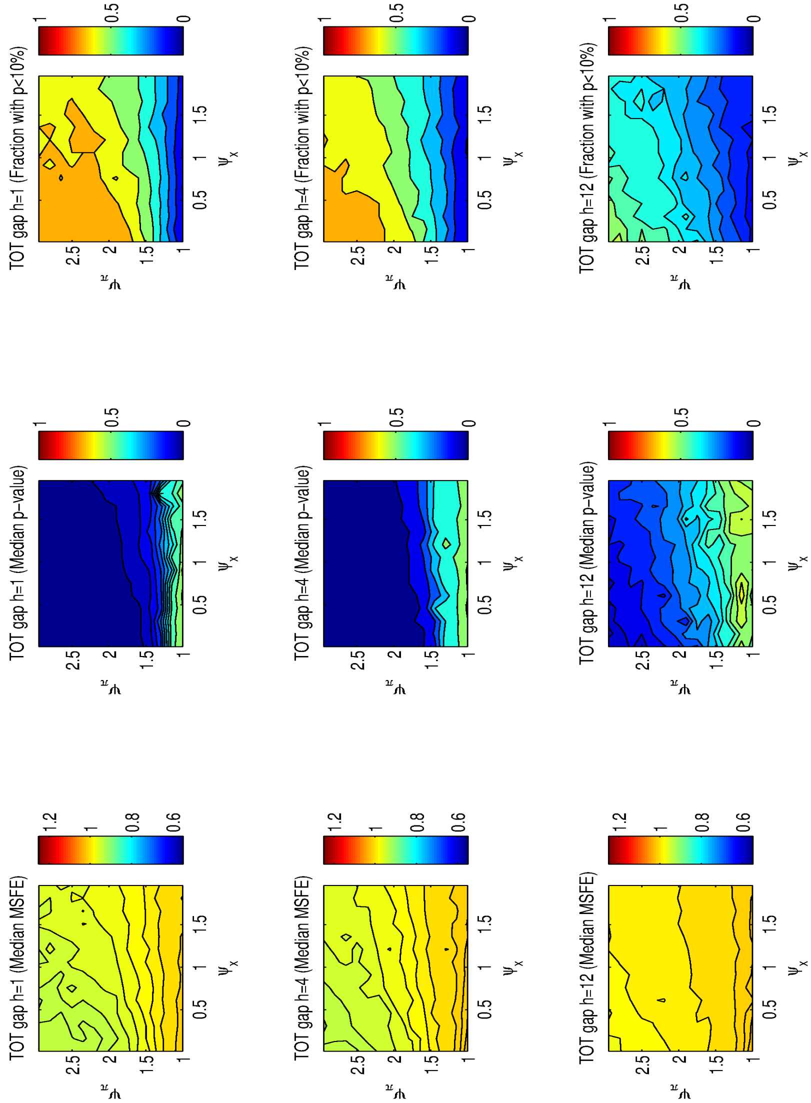

Figure B.29: Model's prediction of the relative MSFEs of forecasts with ToT gap - monetary policy (low inertia)

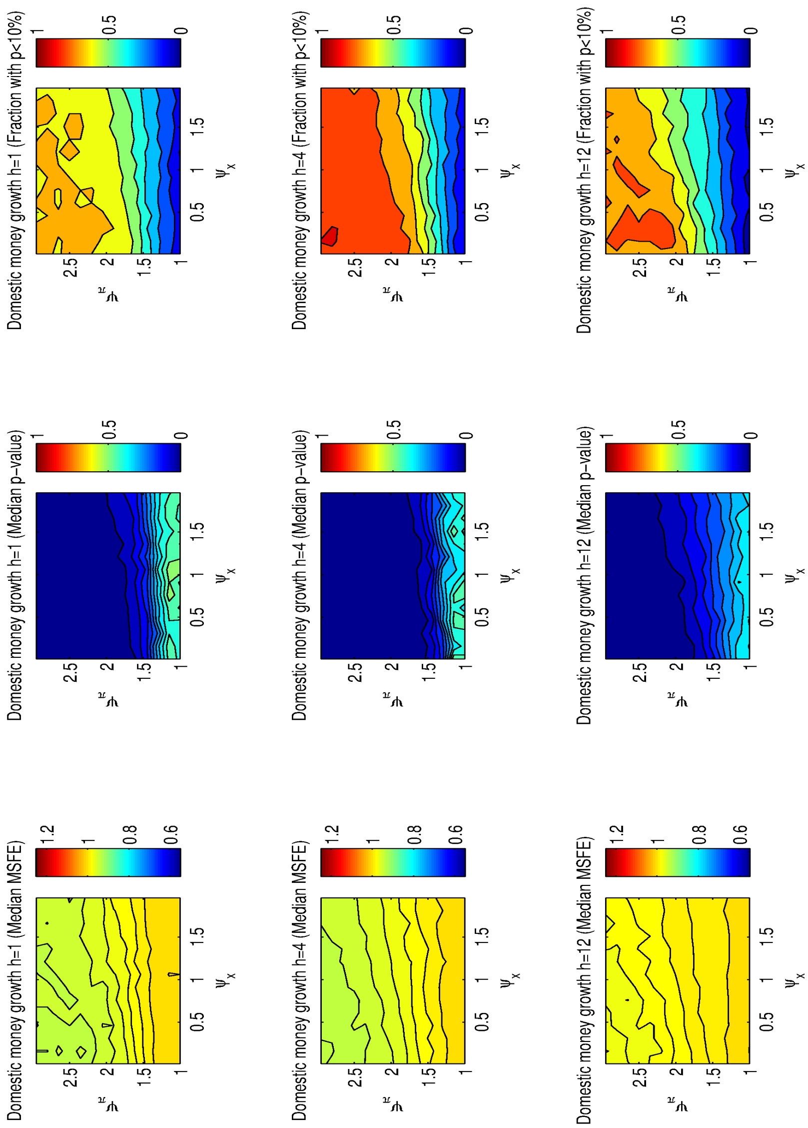

Figure B.30: Model's prediction of the relative MSFEs of forecasts with domestic money-monetary policy (low inertia)

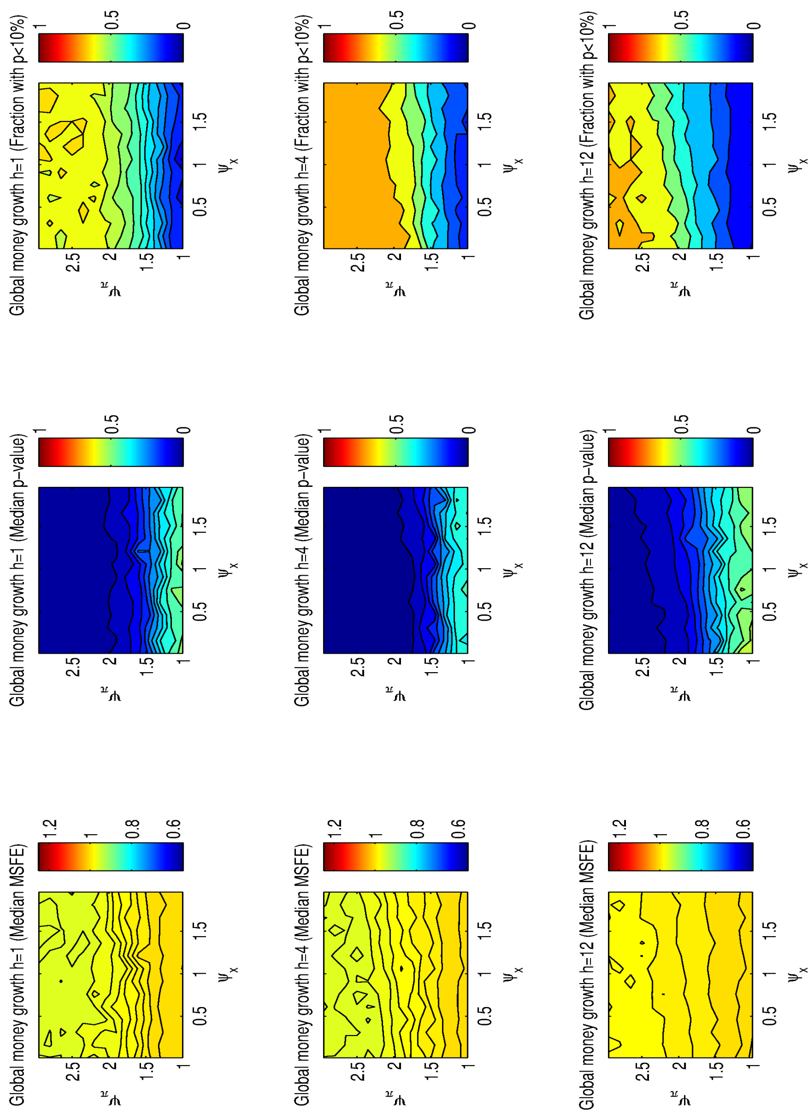

Figure B.31: Model's prediction of the relative MSFEs of forecasts with global money-monetary policy (low inertia)

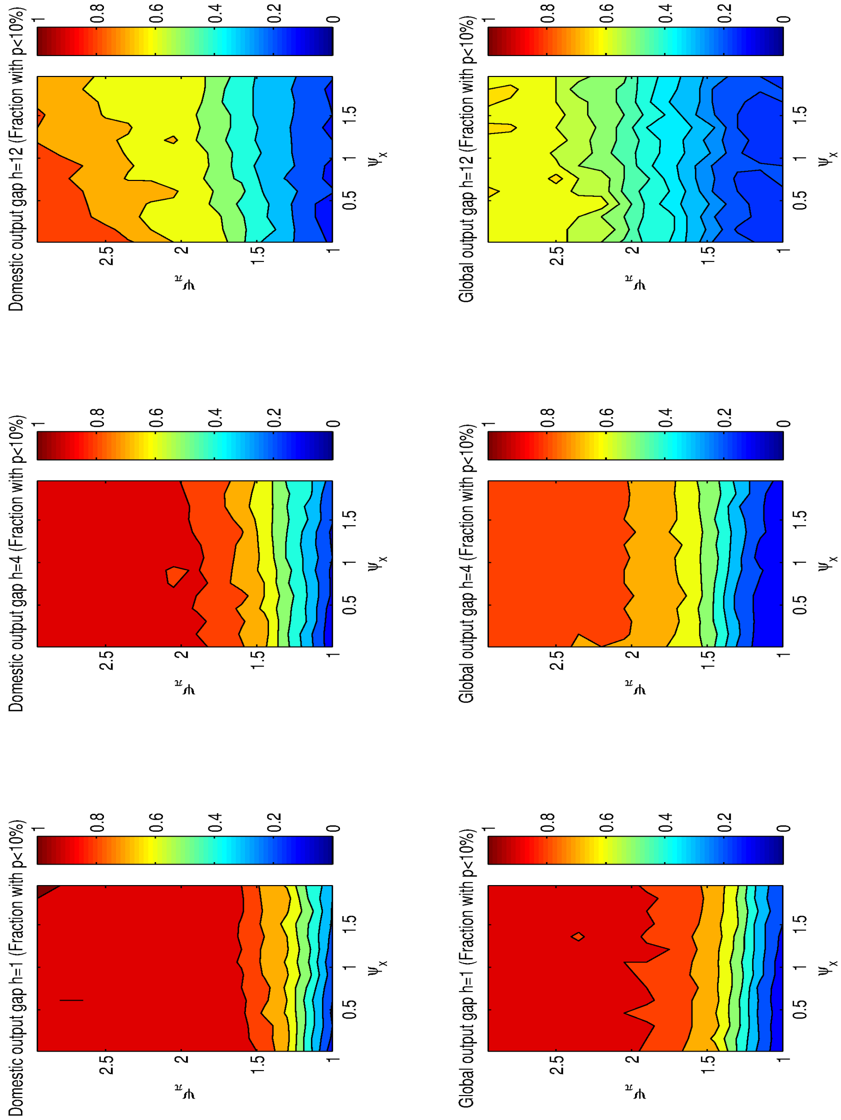

Figure B.32: Comparison of the forecasting performances of simulated domestic and global output gap - monetary policy (low inertia)

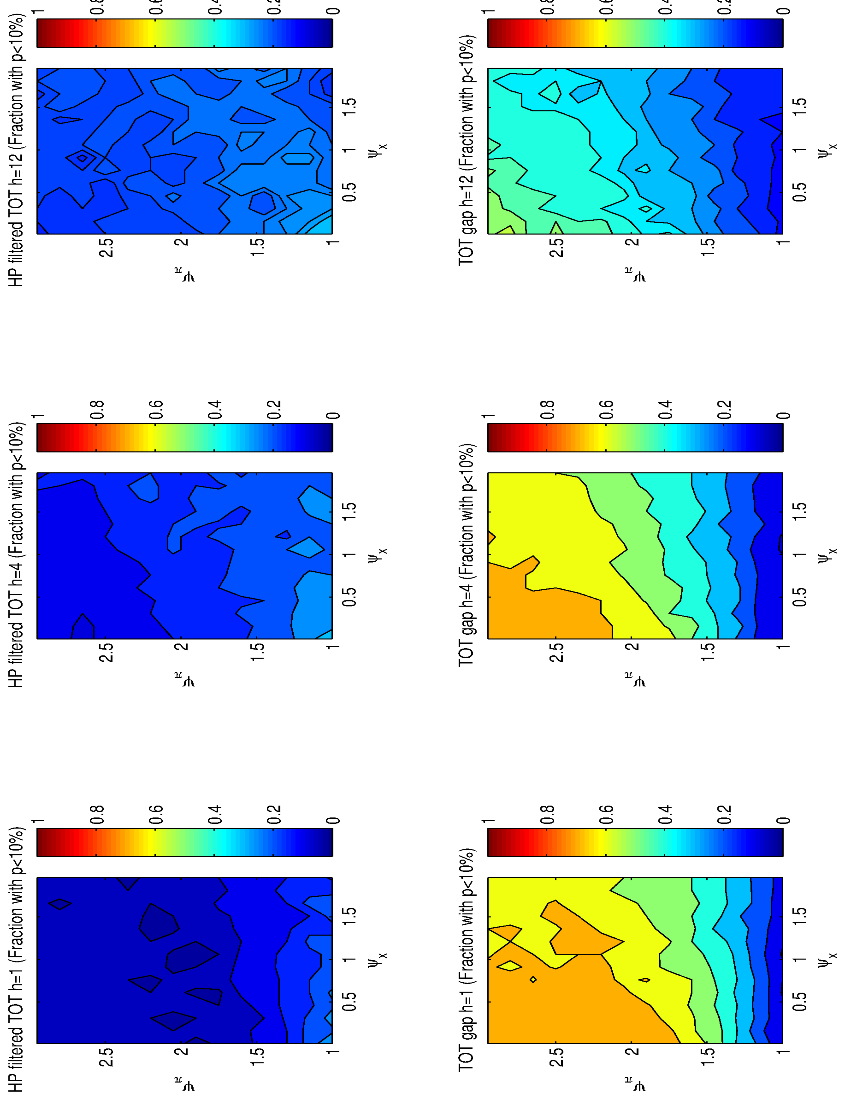

Figure B.33: Comparison of the forecasting performances of simulated HP-filtered ToT and ToT gap - monetary policy (low inertia)

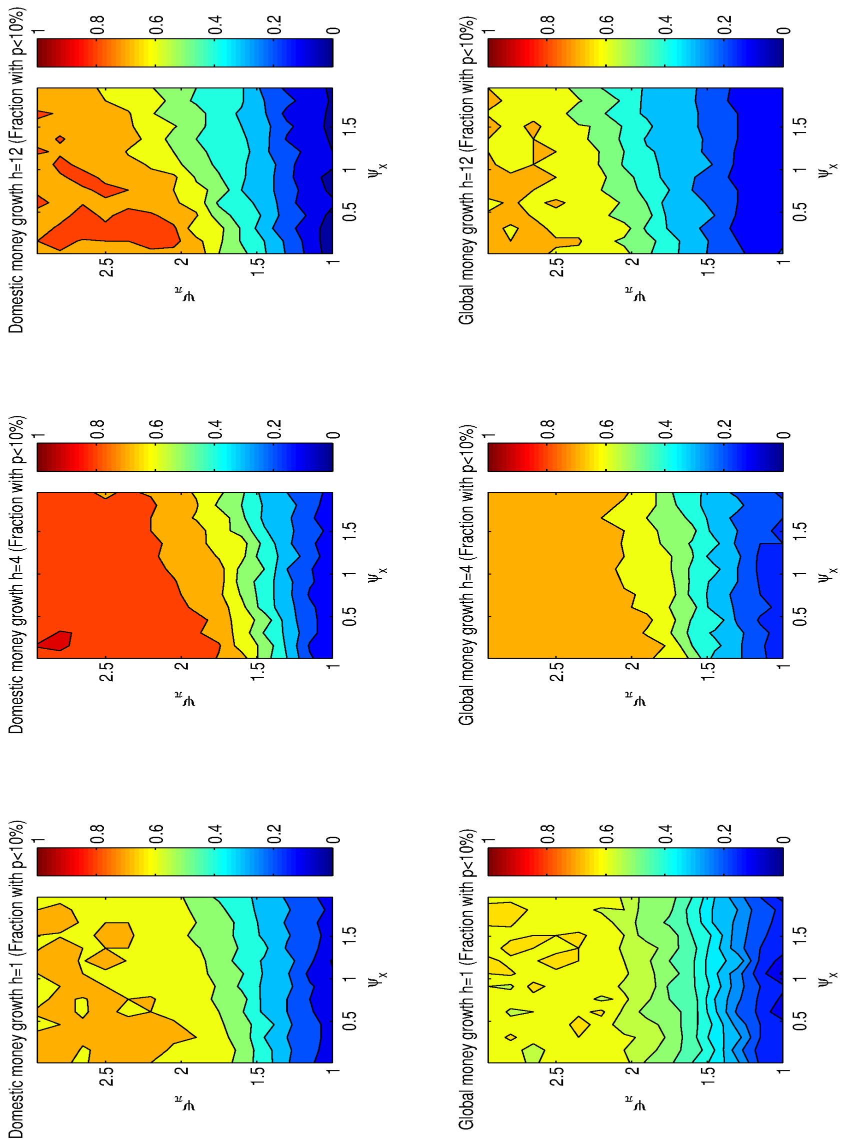

Figure B.34: Comparison of the forecasting performances of simulated domestic and global money- monetary policy (low inertia)

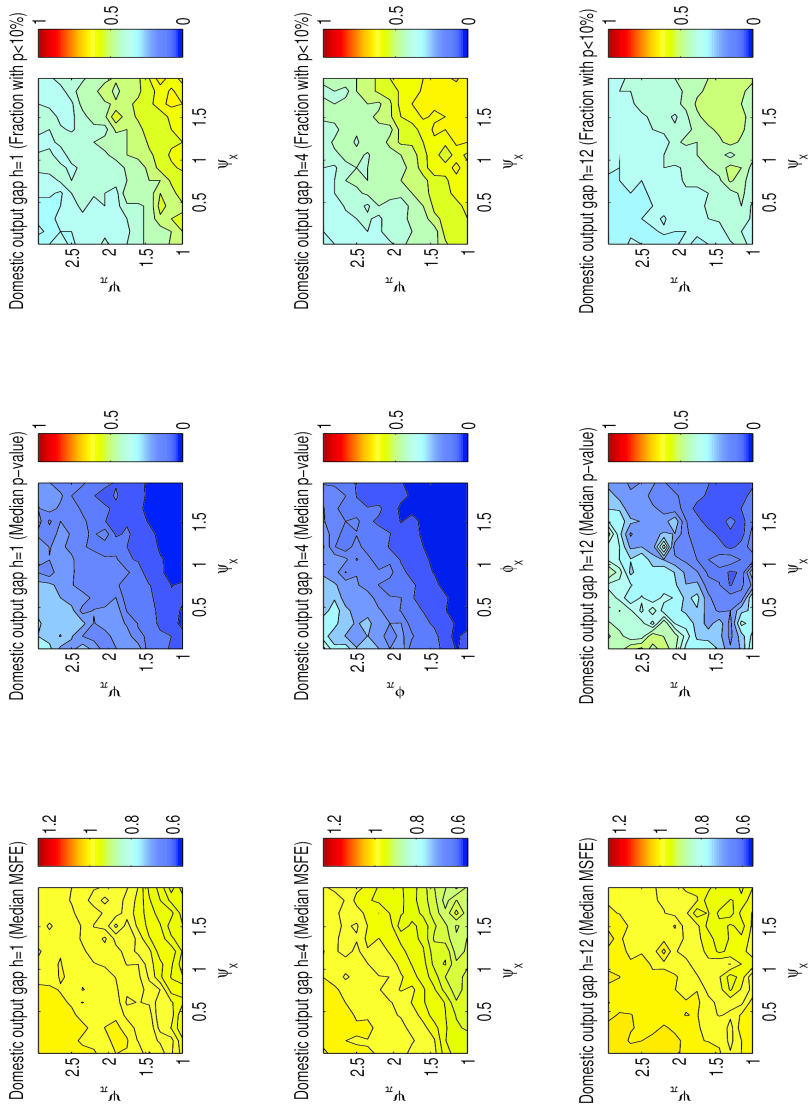

Figure B.35: Model's prediction of the relative MSFEs of forecasts with domestic slack - monetary policy (high inertia)

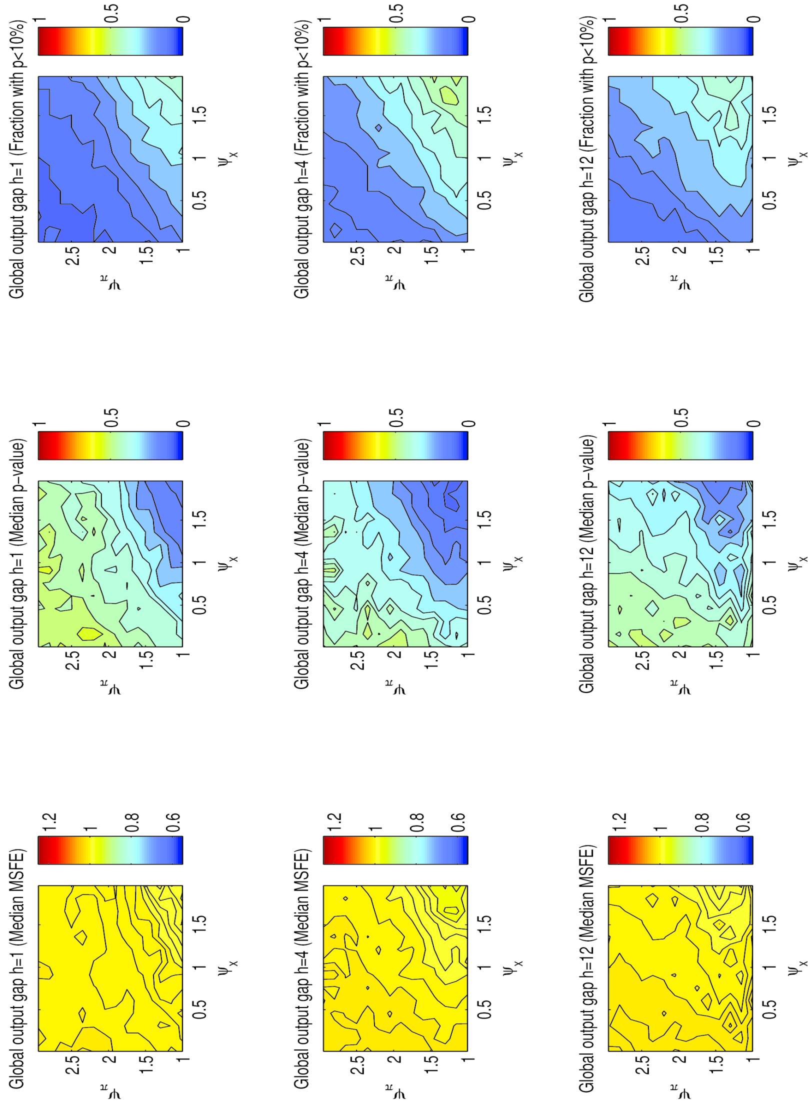

Figure B.36: Model's prediction of the relative MSFEs of forecasts with global slack - monetary policy (high inertia)

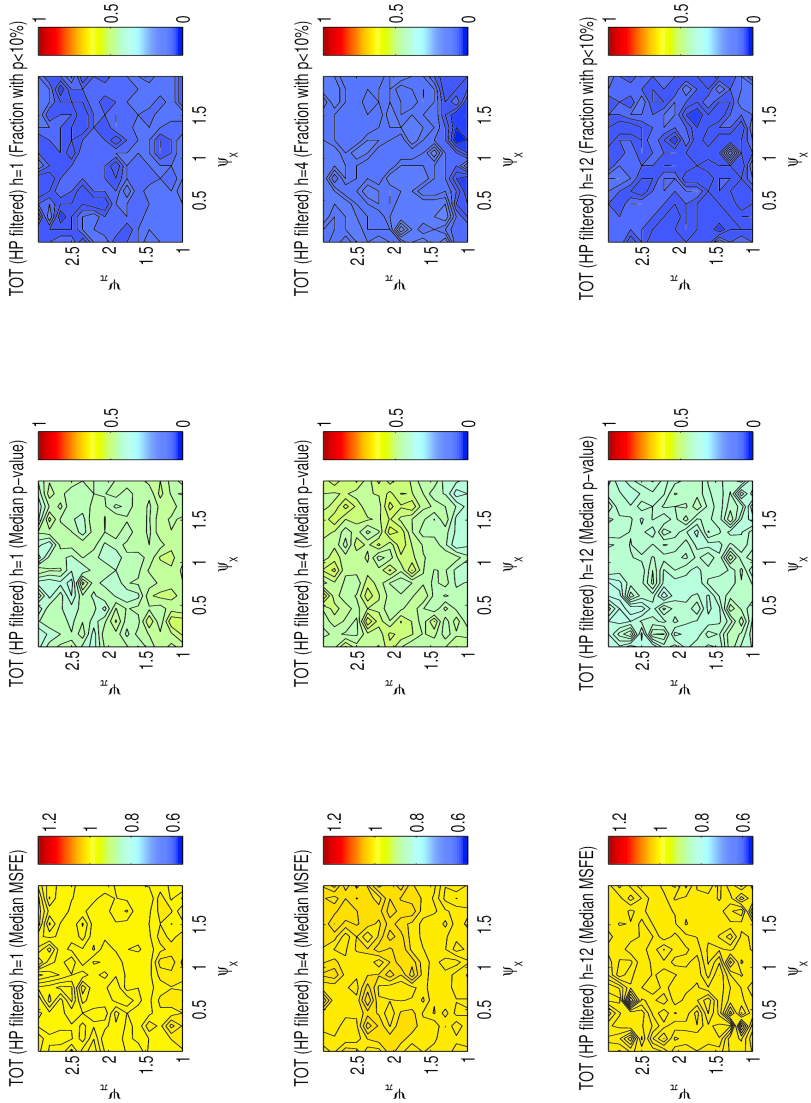

Figure B.37: Model's prediction of the relative MSFEs of forecasts with HP-filtered ToT - monetary policy (high inertia)

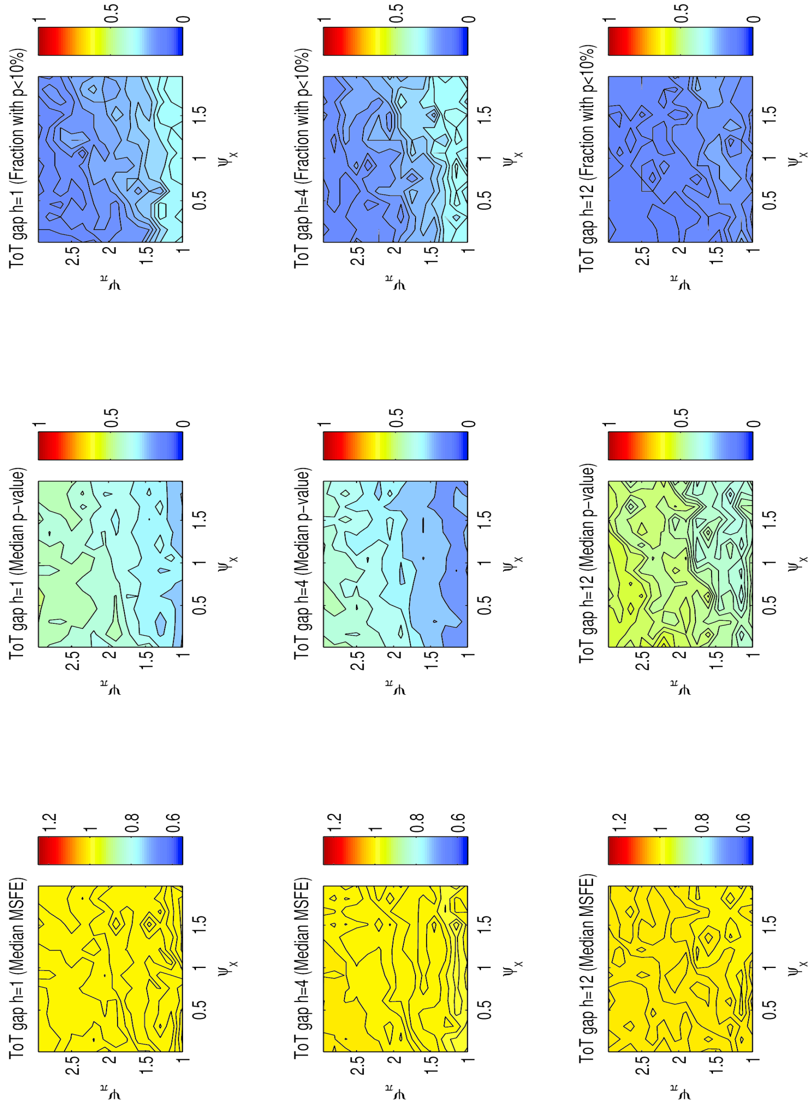

Figure B.38: Model's prediction of the relative MSFEs of forecasts with ToT gap - monetary policy (high inertia)

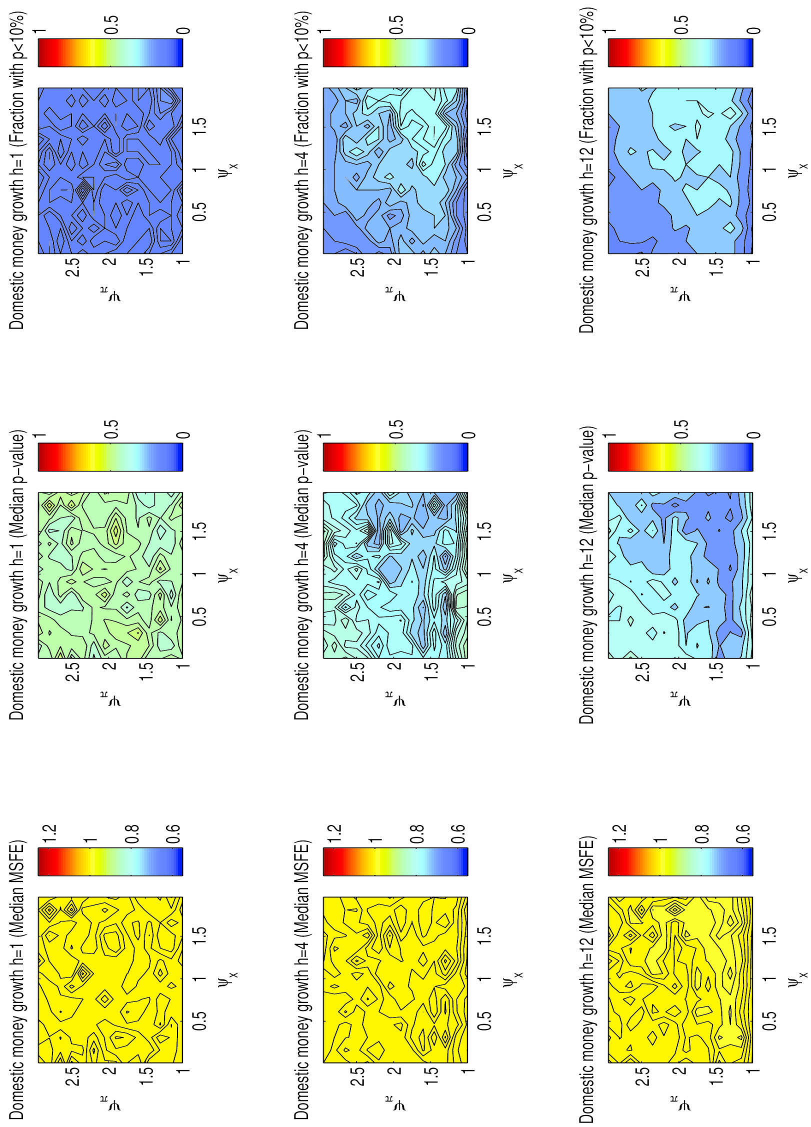

Figure B.39: Model's prediction of the relative MSFEs of forecasts with domestic money-monetary policy (high inertia)

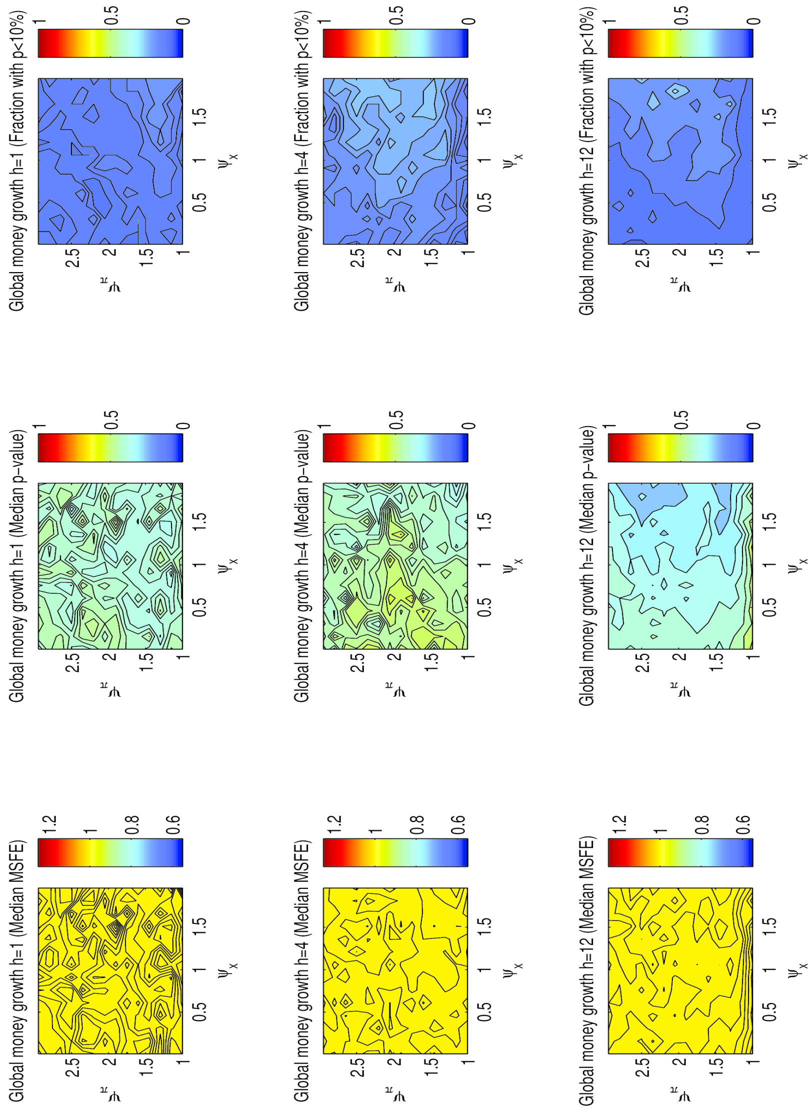

Figure B.40: Model's prediction of the relative MSFEs of forecasts with global money-monetary policy (high inertia)

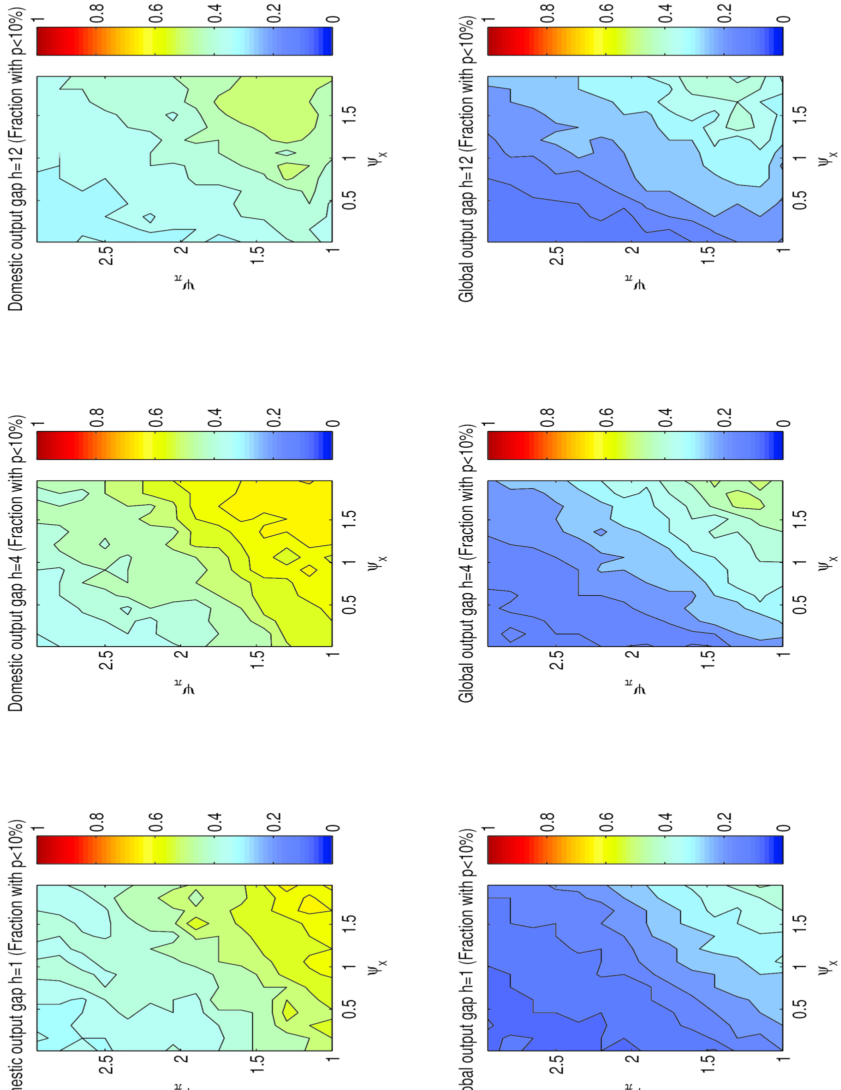

Figure B.41: Comparison of the forecasting performances of simulated domestic and global output gap - monetary policy (high inertia)

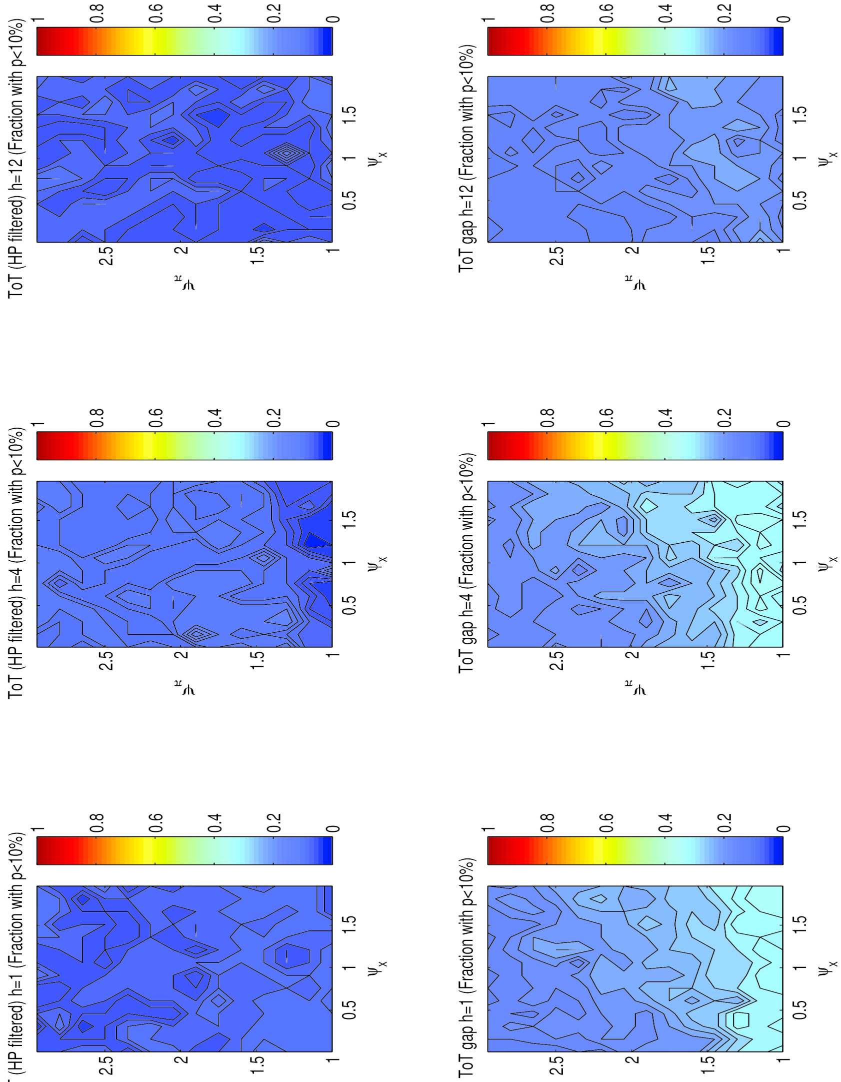

Figure B.42: Comparison of the forecasting performances of simulated HP-filtered ToT and ToT gap - monetary policy (high inertia)

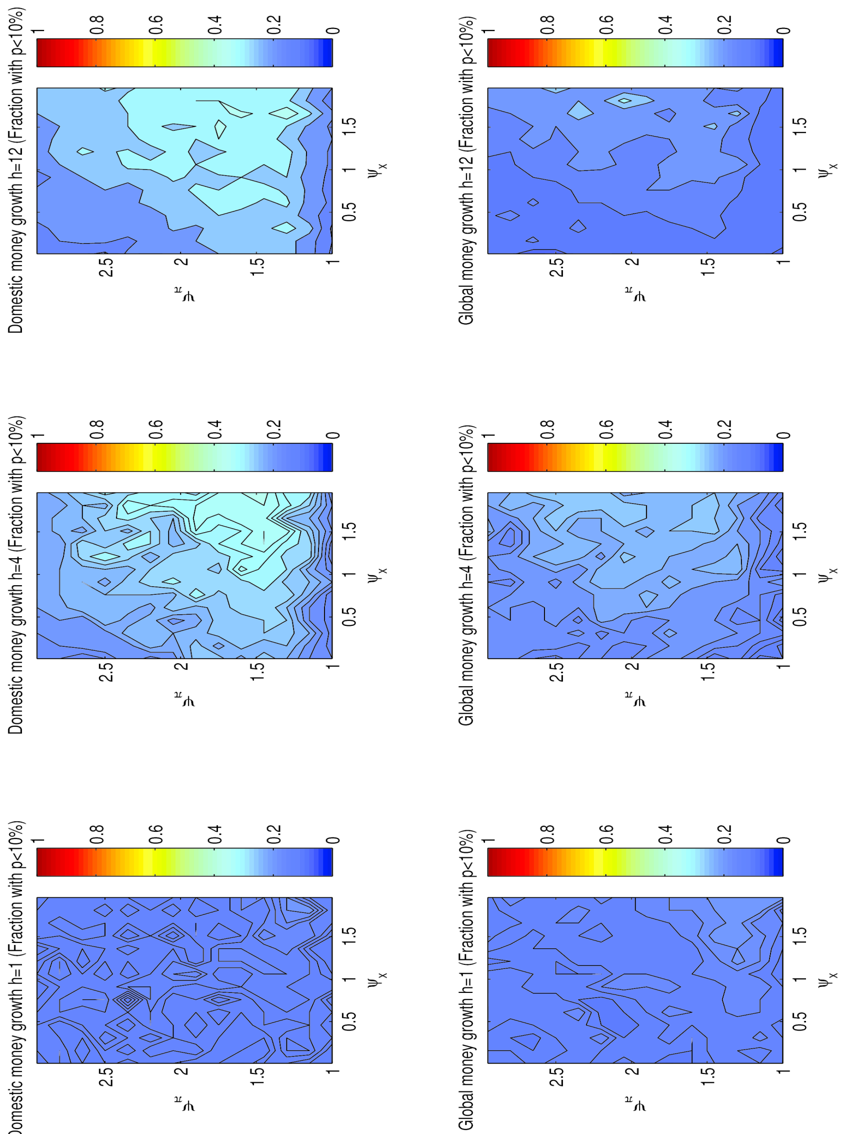

Figure B.43: Comparison of the forecasting performances of simulated domestic and global money- monetary policy (high inertia)

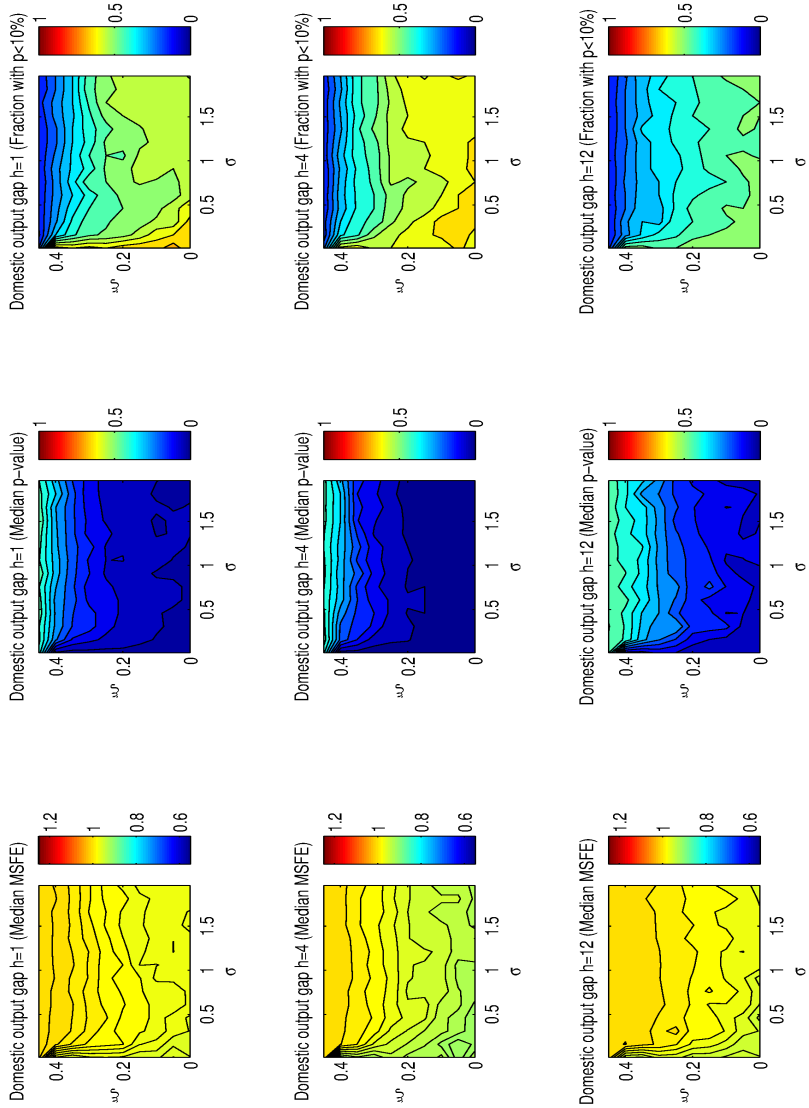

Figure B.44: Model's prediction of the relative MSFEs of forecasts with domestic slack - openness

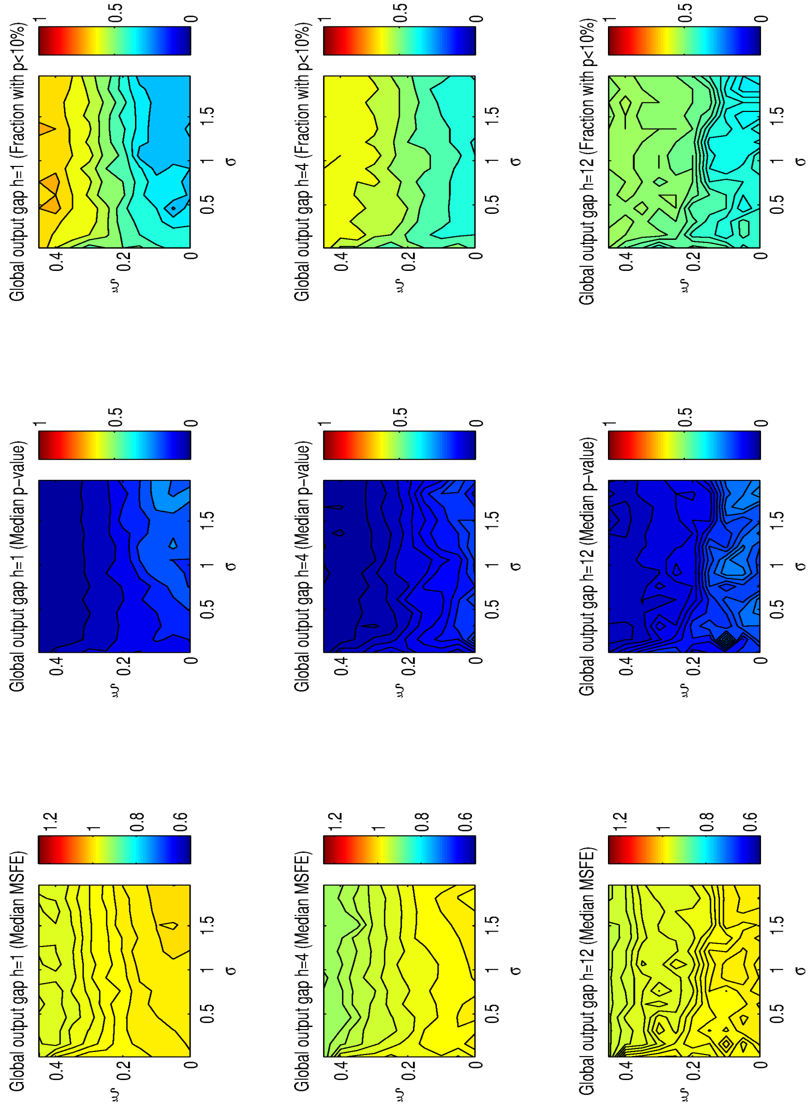

Figure B.45: Model's prediction of the relative MSFEs of forecasts with global slack - openness

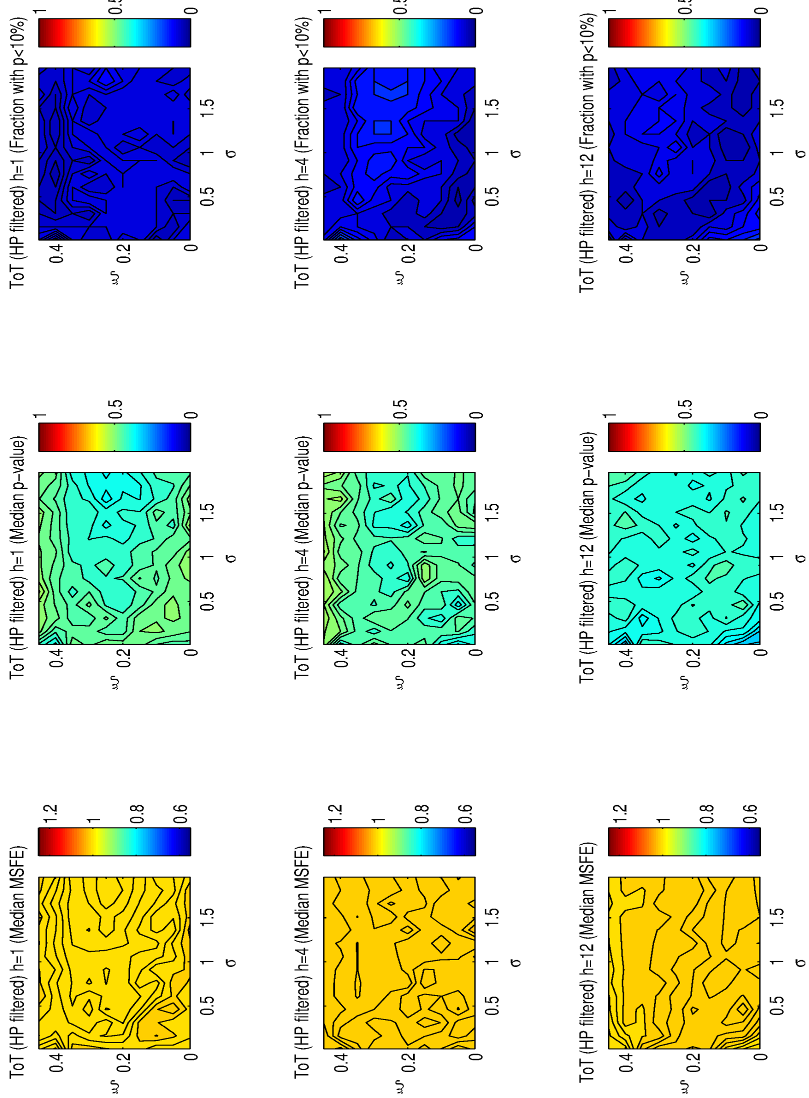

Figure B.46: Model's prediction of the relative MSFEs of forecasts with HP-filtered ToT - openness

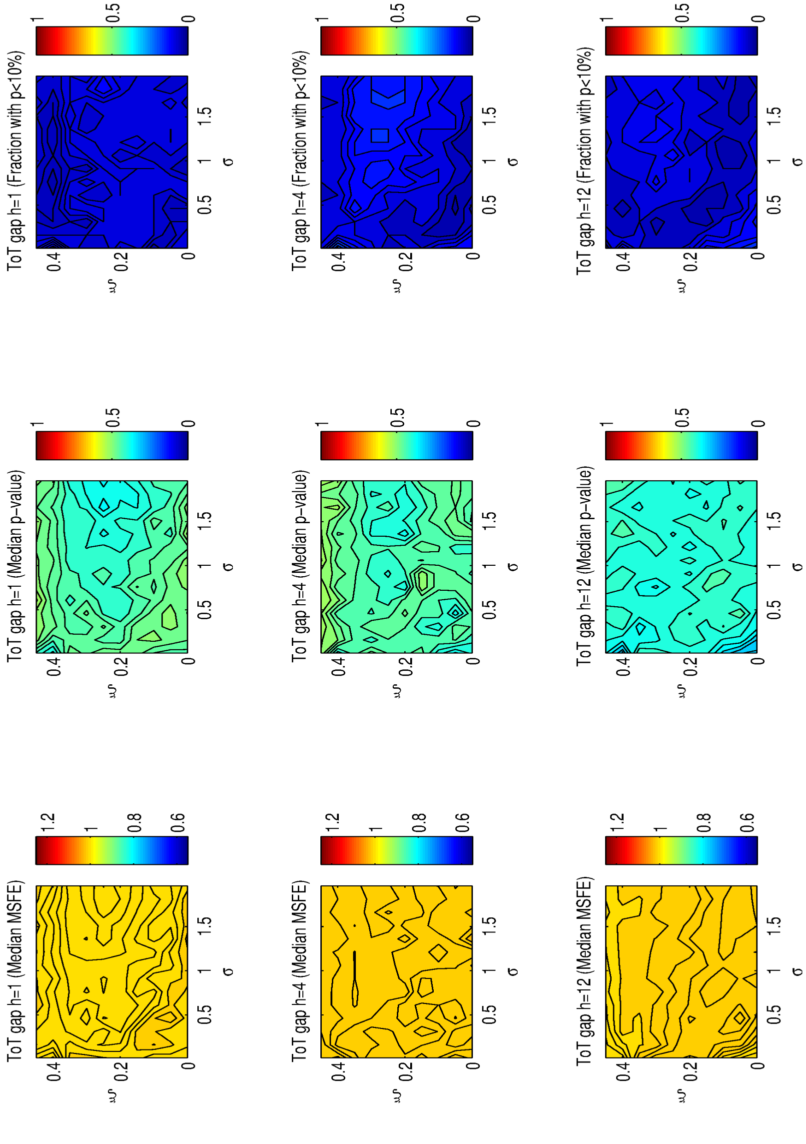

Figure B.47: Model's prediction of the relative MSFEs of forecasts with ToT gap - openness

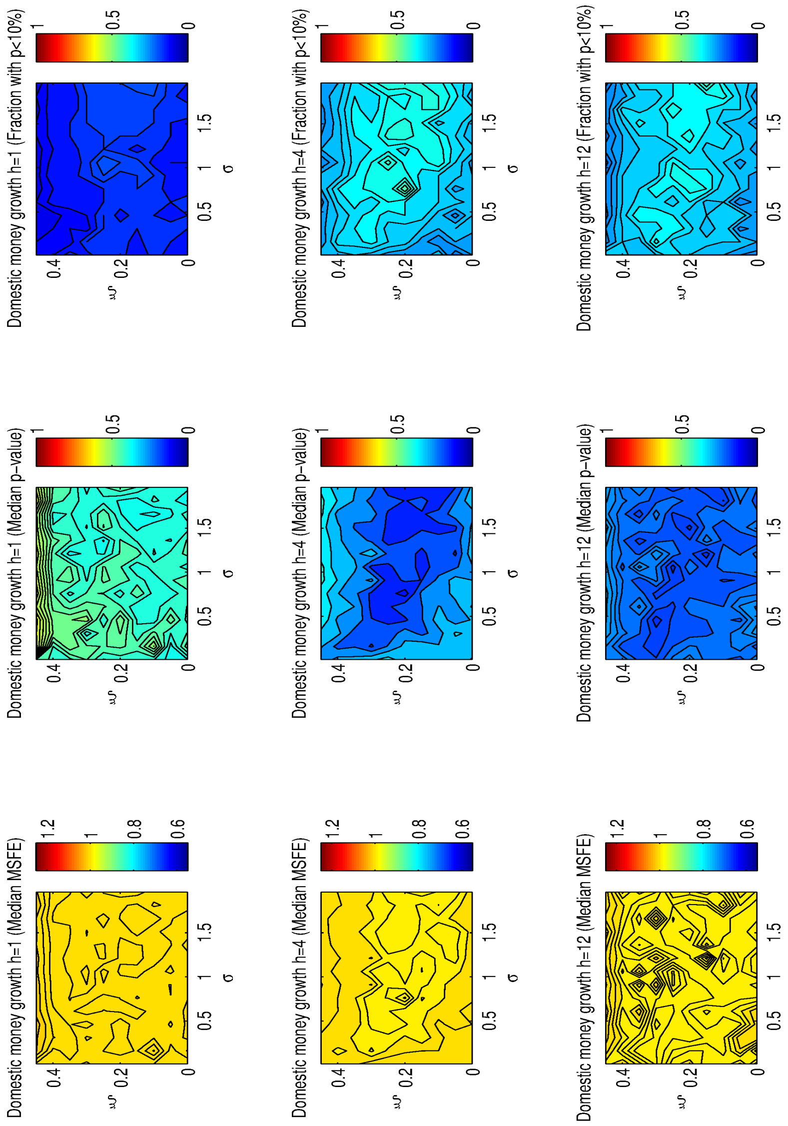

Figure B.48: Model's prediction of the relative MSFEs of forecasts with domestic money-openness

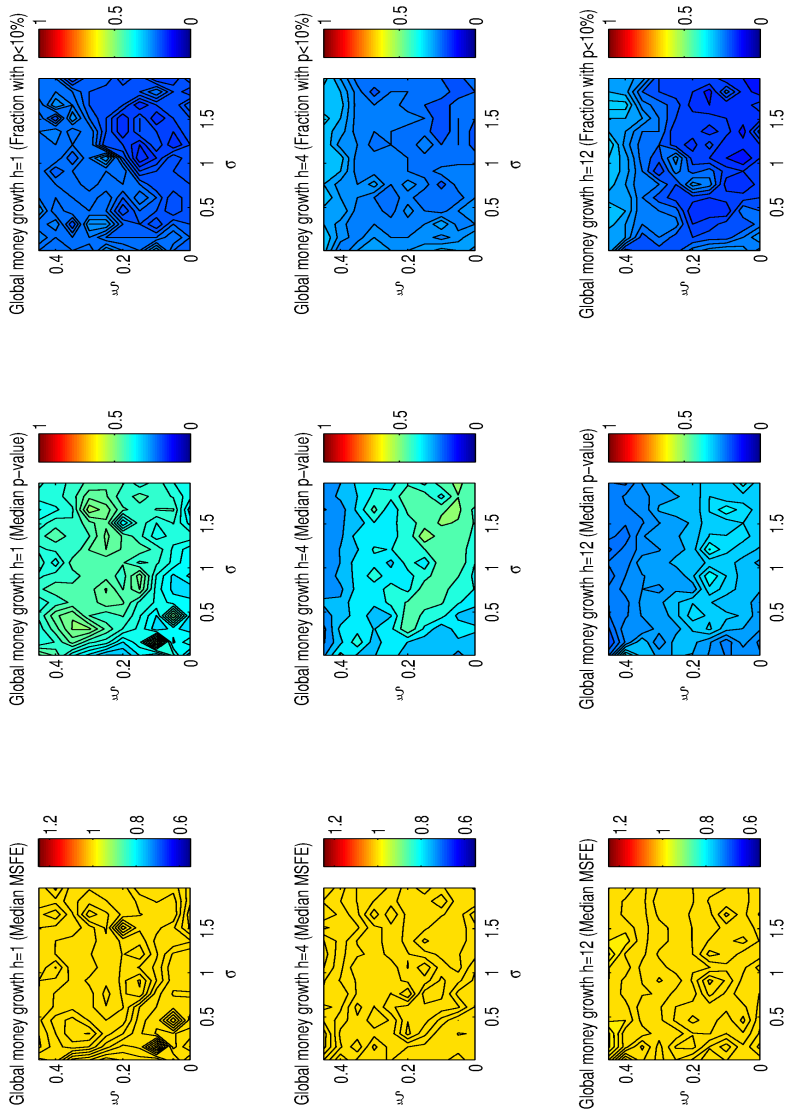

Figure B.49: Model's prediction of the relative MSFEs of forecasts with global money-openness

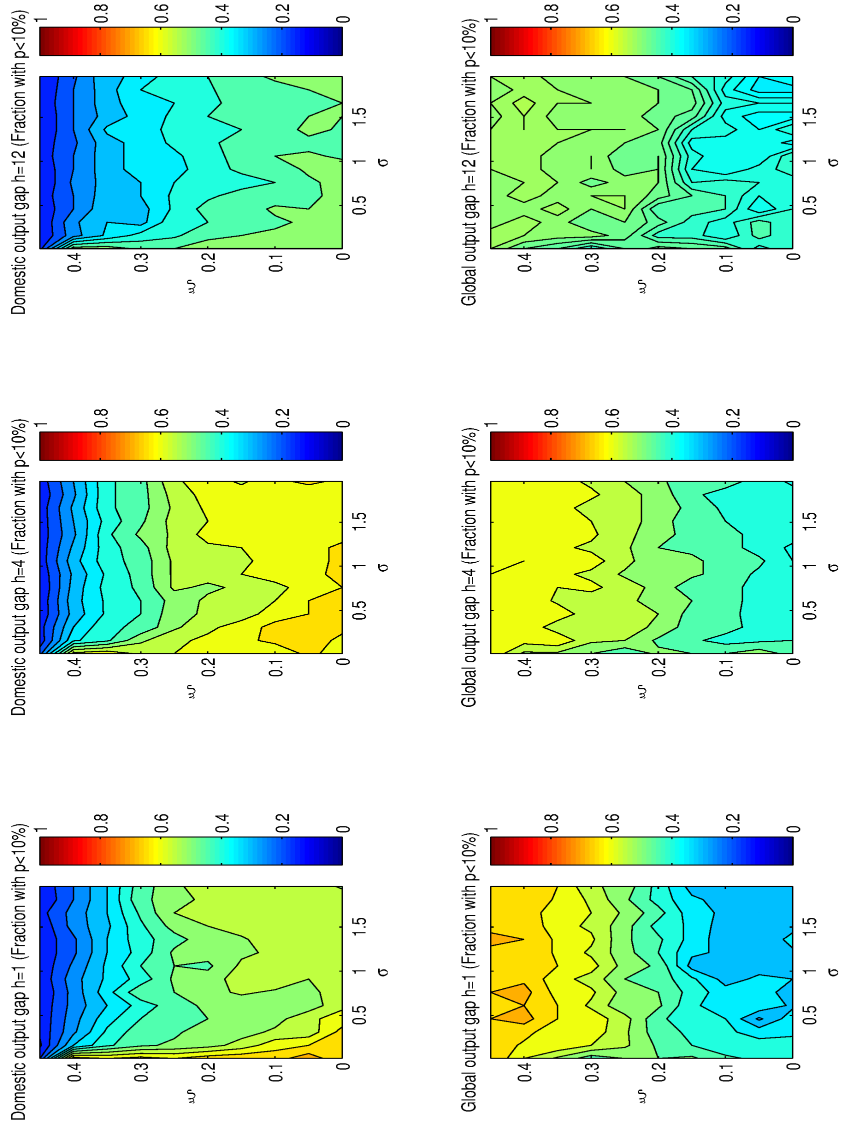

Figure B.50: Comparison of the forecasting performances of simulated domestic and global output gap - openness

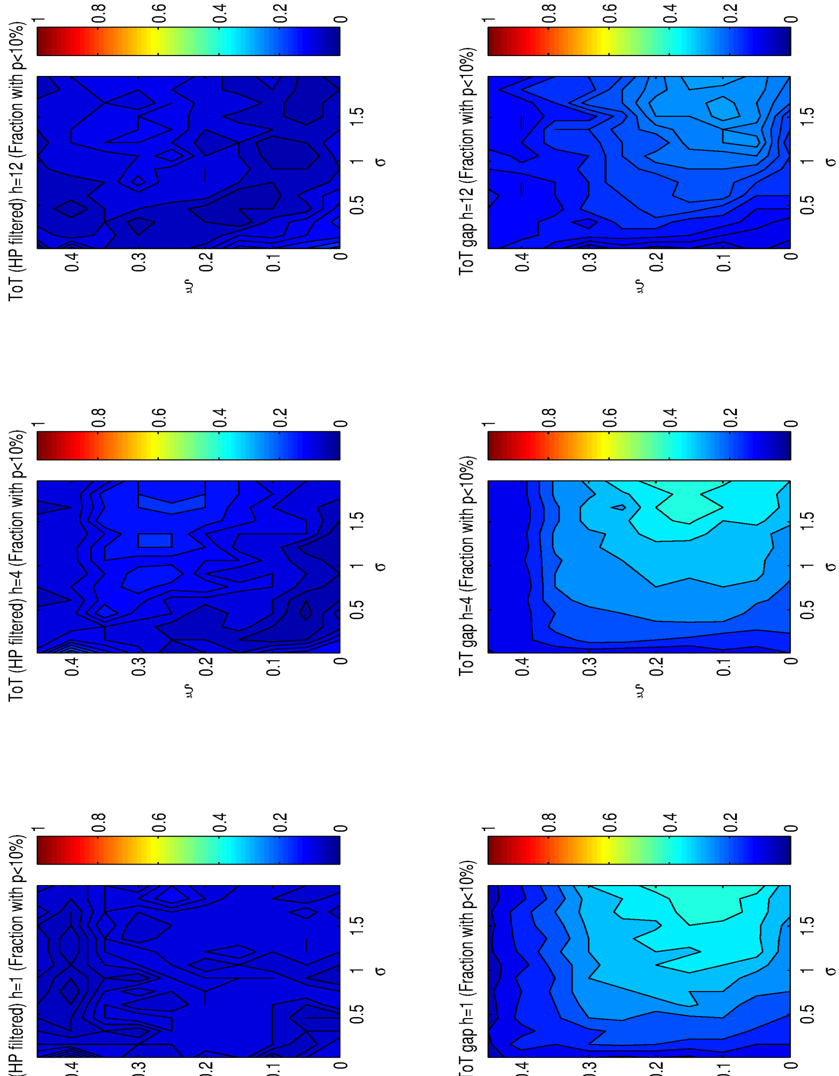

Figure B.51: Comparison of the forecasting performances of simulated HP-filtered ToT and ToT gap - openness

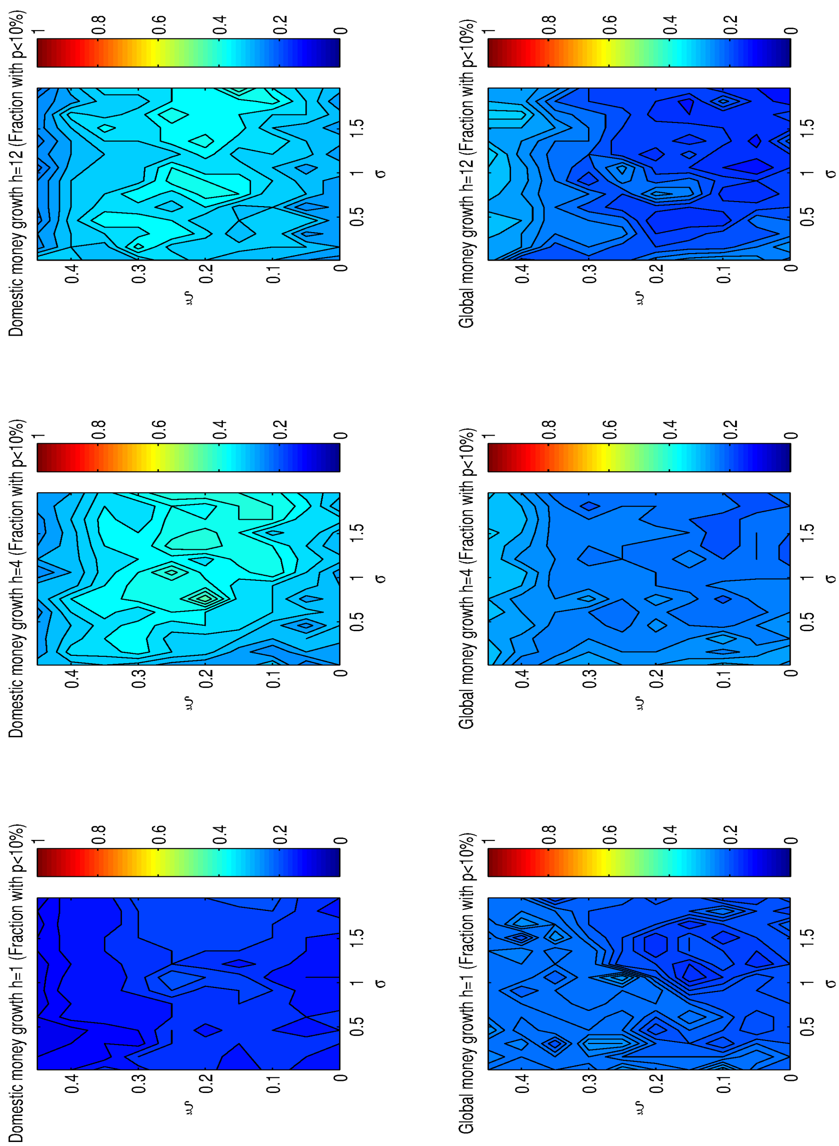

Figure B.52: Comparison of the forecasting performances of simulated domestic and global money- openness

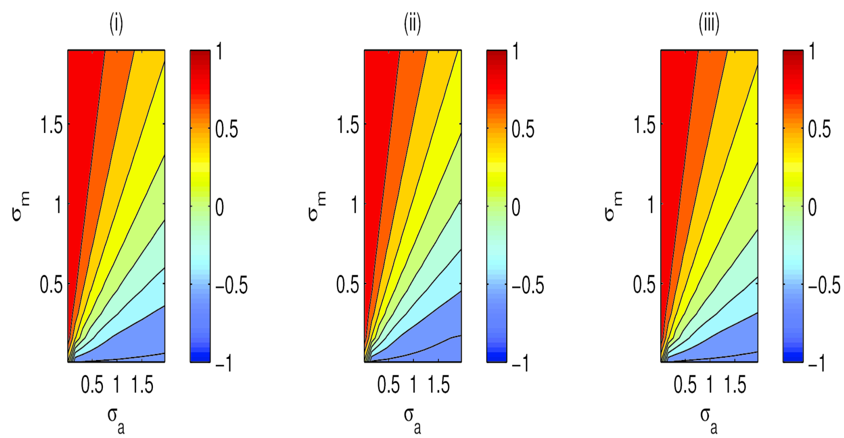

Figure B.53: Correlations of (i) model-consistent domestic output gap and HP-filtered domestic output, (ii) model-consistent global output gap and HP-filtered global output, (iii) model-consistent ToT gap and HP-filtered ToT as a function of the parameters of good luck (symmetric experiment)

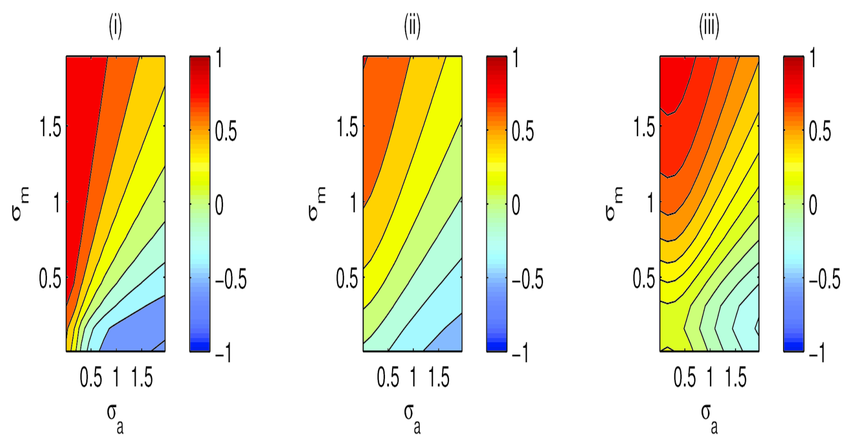

Figure B.54: Correlations of (i) model-consistent domestic output gap and HP-filtered domestic output, (ii) model-consistent global output gap and HP-filtered global output, (iii) model-consistent ToT gap and HP-filtered ToT as a function of the parameters of good luck (asymmetric experiment)

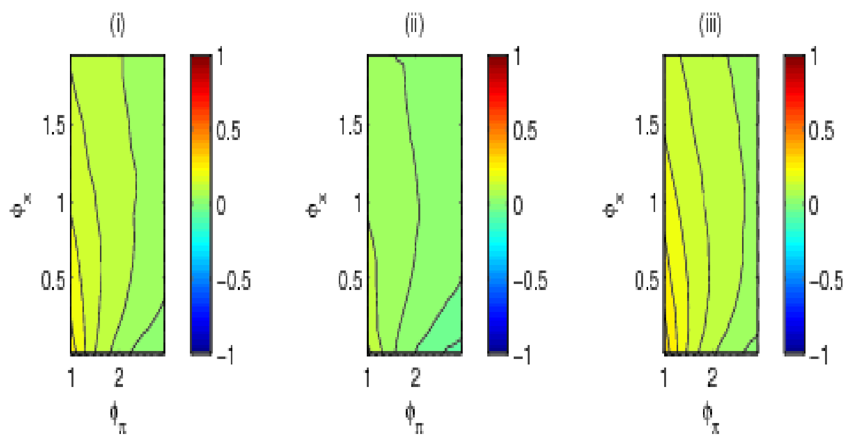

Figure B.55: Correlations of (i) model-consistent domestic output gap and HP-filtered domestic output, (ii) model-consistent global output gap and HP-filtered global output, (iii) model-consistent ToT gap and HP-filtered ToT as a function of the parameters of monetary policy (high inertia)

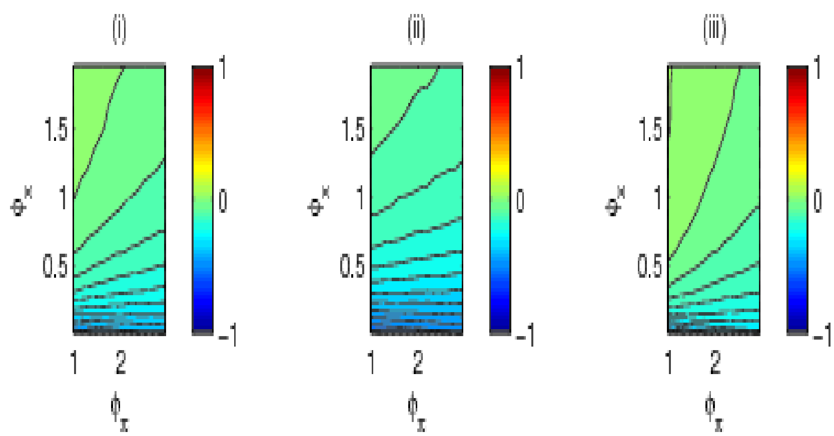

Figure B.56: Correlations of (i) model-consistent domestic output gap and HP-filtered domestic output, (ii) model-consistent global output gap and HP-filtered global output, (iii) model-consistent ToT gap and HP-filtered ToT as a function of the parameters of monetary policy (low inertia)

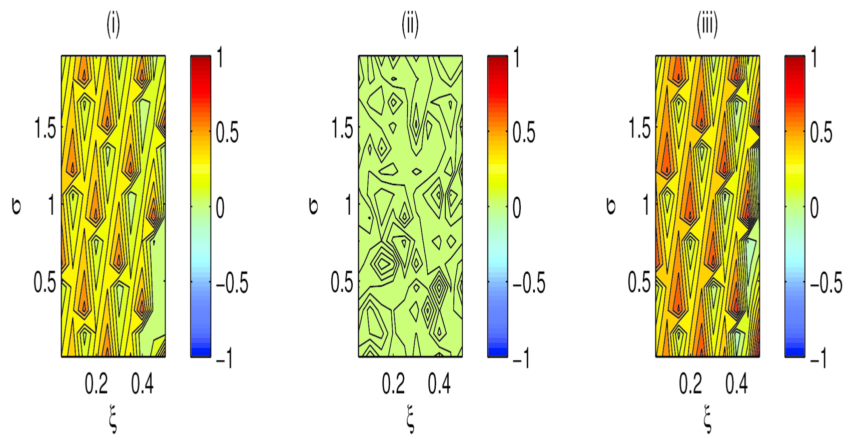

Figure B.57: Correlations of (i) model-consistent domestic output gap and HP-filtered domestic output, (ii) model-consistent global output gap and HP-filtered global output, (iii) model-consistent ToT gap and HP-filtered ToT as a function of the parameters of openness

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